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## SUMMARY OF CONTENTS

Vol. VII: Nos. I—10, Jan.—Dec., 1942


| | Page |
|---|---|
| Infra-Red Radiation and Equipment: Their Application to Industrial Heat Processes, by R. Maxted, B.E., A.M.I.E.E., F.Inst.P., F.I.E.S. | 1 |
| Planning for Daylight, by John W. T. Walsh, M.A., D.Sc., M.I.E.E., F.I.E.S. | 19 |
| The Location of Fluorescent Tubular Lamps with respect to the Object Illuminated, by M. W. Peirce, F.I.E.S. | 35 |
| Gas Lighting Under Low Pressure Conditions, by F. C. Smith, M.Inst. Gas E., F.I.E.S. | 36 |
| Revealing of Station Names and Platforms under Black-Out Conditions, by G. W. Golds, F.I.E.S. | 37 |
| A Convenient Means of Dimming Lights on D.C. Circuits, by Harold Bright, M.A., M.R.I., F.I.E.S. | 39 |
| The Measurement of Transmission Factors of Diffusing Materials, by H. Buckley, D.Sc., F.Inst.P., F.I.E.S. | 39 |
| Atmospheric Absorption of Light in Factories, by E. B. Sawyer, F.I.E.S. | 40 |
| Report of the Council for the Session 1941-42 | 62 |
| Advance Planning in Lighting Reconstruction, by Howard Robertson, F.R.I.B.A. | 51 |
| Fluorescent Light Sources and their Applications, by J. N. Aldington, B.Sc., A.L.C., F.Inst.P., F.I.E.S. | 57 |
| Population Densities and the Heights of Buildings, by H. E. Beckett, B.Sc. | 75 |
| Lighting in the Woollen and Worsted Industry, by T. C. Holdsworth, A.M.I.E.E., F.I.E.S., J. W. Howell, D.L.C., A.M.I.E.E., F.I.E.S., and J. H. Jackson, B.Sc., A.M.I. Mech. E. | 81 |
| The Eye, by J. R. Mitchell, M.C., M.B., Ch.B., D.P.H. | 101 |
| Street Lighting: Past, Present and Future, by G. H. Wilson, B.Sc.(Eng.) A.M.I.E.E. *(Fellow)* | 111 |


Notes on Recent Meetings and Events——Fellowship——Applications for Membership——Election of Officers and Council——Annual General Meeting

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# INFRA-RED RADIATION AND EQUIPMENT: THEIR APPLICATION TO INDUSTRIAL HEAT PROCESSES

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*(Paper read on Tuesday, December 9th, 1941, at 2.30 p.m.)*

Perhaps nothing is more pleasing and yet more provoking than a contemplation of achievements and potentialities in the realm of radiant energy. Starting from some material substance excited by heat, electric discharge, or other means, this form of energy travels in electro-magnetic waves and is ultimately absorbed by material substances. Newton showed that light could be separated into a spectrum, and Herschel found considerable energy beyond the red limit. Their successors were not content to complete this analysis of solar radiation, but have, by artifice, caused energy to appear at wavelengths not yet found in nature.

Experiment and deduction have produced two ideas of fundamental significance—the dependence of characteristic effects primarily on wavelength, and the conception of a continuous electro-magnetic spectrum. Limitless possibilities are conjured up by the association of these two ideas, and the familiar

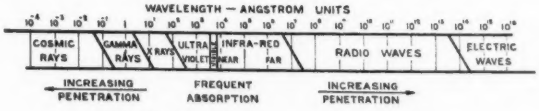


Fig. 1. The Electromagnetic Spectrum.

chart of Fig. 1 is but a cartoon—it emphasises the more prominent features and leaves infinitely more to the imagination.

Large and vaguely classified regions are to be expected at an early stage in this development. Nor is it surprising that experimental discoveries should have carried investigators well clear of the visible region, leaving the neighbouring ultra-violet and infra-red wavelengths relatively unexplored and ill-defined. But it is in some respects remarkable that the infra-red region did not provide the first instance of development engineering in the dark regions. Infra-red radiation was probably the first produced artificially by man, who for ages has spent long periods contemplating infra-red sources, pleasantly aware of the radiation. It is perhaps an indication of the relaxing properties of infra-red that it should receive such rapt attention and yet be spared more subtle exploitation.

Despite this long history of appeasement, infra-red radiation can and must play an important part in speeding war production. Most war-time products require a protective finish, and synthetic enamels or lacquers are commonly applied. Such finishes can be baked in a few minutes with infra-red equipment, as compared with an hour or more in the conventional convection oven. In fact, infra-red processes are particularly well suited to war-time conditions of production in several practical respects.

## Scope of Paper

The purpose of this paper is to discuss the application of infra-red radiation to the heating of materials, as, for example, in the baking of paint finishes.

Radiant heating techniques still depend rather more on direct experiment than upon a full understanding of wavelength effects, the properties of materials, or the physics of processes. If optimum combinations of materials and wave-bands are to be selected, a thorough knowledge of the spectral characteristics of materials is needed. The first part of the paper is, therefore, an attempt to outline certain physical aspects of the subject and to indicate the type of detailed data essential to a scientific approach.

The second part of the paper deals with radiant energy sources and engineering problems in the design of applicational equipment. Engineering practice is on much firmer ground in the production and control of energy, for the experience of the lighting engineer is quite readily adapted, at least to present-day infra-red sources. Lighting and radiant heating show a general resemblance even in the physical aspect, especially if absorption and reflection are interchanged in significance. As regards the spectral characteristics of materials, perhaps the role of selective penetration in heating is somewhat analogous to that of colour in vision.

## Heating with Radiant Energy

One effect of the absorption of radiant energy is the transformation of the radiation into sensible heat within the absorbing material. Radiant heating depends solely upon this effect, and heat is received by the absorbing material instantly upon exposure to the radiation. The terms "radiant heat" and "heat rays" are usually applied exclusively to the infra-red wavelengths, but the essential effect is by no means confined to this region. It is therefore worth while considering the practical value of other wavelengths.

Absorption is, of course, essential in the utilisation of radiant energy at all wavelengths, and reflection is usually necessary. A review of the known effects of the electro-magnetic spectrum reveals, however, that most materials are more transparent at the longer and shorter wavelengths, and that the ultra-violet, visible and infra-red wavelengths together form a region of least penetration. This region of abundant absorptions is indicated for a process such as radiant heating which depends upon absorption, and which must be applicable to many substances. Most materials show appreciable absorption at some waveband in this region.

But absorption does not always mean the transformation of energy into heat, and this is especially

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true of the ultra-violet wavelengths, which are absorbed by many materials. It is, of course, well known that a fluorescent substance will re-radiate energy at visible wavelengths, but the incident ultra-violet is more often transformed into heat. Ultra-violet energy may also change the structure of the absorbing material, as in the case of photo-chemical reaction. Such effects extend into the visible region, but are fewer at the longer visible wavelengths, and probably negligible at the near infra-red. Photo-chemical changes may be undesirable in themselves, rather than on account of the energy losses involved.

Substances receiving visible energy will reflect wavelengths characteristic of the "colour" of the material, while other visible wavelengths are absorbed and converted into sensible heat. The reflection of energy is a notable feature of the visible spectrum, and at first thought these wavelengths may seem unsuited to radiant heating. On the basis of the proportion of incident energy transformed into heat, however, the visible wavelengths may be better suited to some materials than infra-red radiation.

The outstanding characteristic of the infra-red region is that the production of heat is practically the only primary effect of the absorption of energy. There are, of course, secondary effects accompanying the desired rise in temperature of the absorbing material. These include the intended structural changes in the substance, and the re-radiation of energy at longer wavelengths.

In general, then, extensive absorption occurs at all these wavelengths, and sensible heat is the most common result. Other things being equal, regions are preferred where irrelevant or undesirable effects are least. Such effects decrease with increasing wavelength, and are practically non-existent in the infra-red region.

Considerations of this nature do not alone explain the use of the near infra-red and visible wavelengths in present-day practice. The choice is due equally to the spectral energy distribution of convenient and efficient sources, and to the spectral characteristics of the materials most involved in radiant heating processes.

### Spectral Characteristics of Materials.

When any substance is irradiated the incident energy is partly reflected, partly transmitted and partly absorbed. For a given material the magnitude of each effect varies with wavelength throughout the electro-magnetic spectrum. The direct effect of absorption may be the reradiation of energy at longer wavelengths, a change in the state or structure, or the production of sensible heat within the absorbing substance.

The usual purpose of radiant heating is to produce a change in state or structure, as in dehydration, or the stoving of enamels. It is believed that the results achieved in practice are due to the application of heat alone, and do not depend upon a change in structure arising from any direct action of the radiation. It is conceivable that future developments may lead

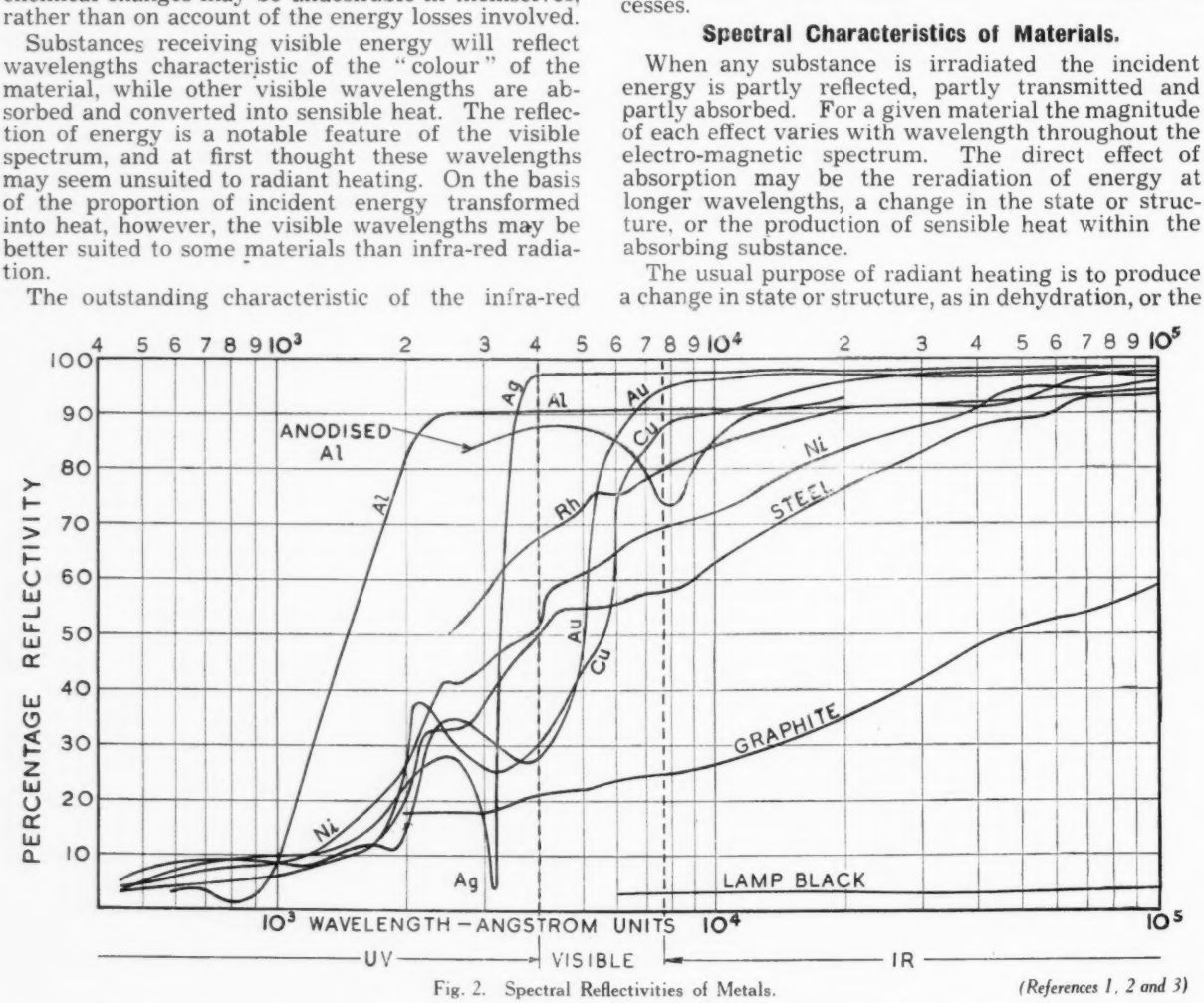



Fig. 2. Spectral Reflectivities of Metals. *(References 1, 2 and 3)*

(1) G. B. Sabine, Phys. Rev., **55**, 1,064 (1939).
(2) W. W. Coblentz and R. Stair, B.S.J. Research, **22**, 93 (1939).
(3) Smithsonian Tables.

to the utilisation of direct spectral effects, but the aim in present-day techniques is to apply heat.

Interest therefore centres in the thermal effects of absorption, and the spectral characteristics of materials will be studied on this basis only. It should, however, be noted that the material receiving heat treatment is not necessarily the absorbing substance. Thus an enamelled metal sheet may be irradiated from the back, or a transparent lacquer may be heated partly by absorption in the underlying substance.

The first object is to select wavelengths at which the reflectivity of the absorbing material is low. From Fig. 2 it is seen that some metals—especially when polished—are more suitable for the redirection of energy in the infra-red region.

In general the characteristics of metals show a gradual change from nearly 100 per cent. reflection of the far infra-red to almost complete absorption of the extreme ultra-violet wavelengths.

Silver, gold, copper, and aluminium all maintain a high reflectivity through the infra-red region, and then show relatively sharp declines, gold and copper in the visible region, silver in the near ultra-violet, and aluminium a more gradual fall extending into the extreme ultra-violet. Anodised aluminium shows a sudden dip around 8,000 A.U., and this is probably due to absorption in the hydroxide film constituting the protective surface. These metals are of great practical value in the control of radiant energy, and it is clear that radiant heating techniques must utilise wavelengths where at least one material is highly reflecting. Gold, copper, and silver could be heated effectively at visible and ultra-violet wavelengths, using aluminium reflectors. Aluminium itself presents obvious difficulties, but there are practical solutions. The radiant heating of bare metals is not a common industrial problem, but it does sometimes arise in the case of sheet steel parts. Fig. 2 shows that even *polished* steel is fairly absorbent in both the visible and near infra-red regions.

Extreme transparency is also to be avoided except in enclosures for radiant sources; but in *absorption during penetration* lies one of the most important potentialities of the radiant energy process. The heating of water films provides a good illustration of this effect. Fig. 3 shows that the transmittance of water varies continuously with wavelength from nearly 100 per cent. in the visible region to the almost complete opacity of a 1 mm. film in the region of 25,000 A.U. Near infra-red energy will be absorbed at different depths depending upon wavelength, and a source having a continuous spectrum in this region is well suited to the production of heat at all depths in a water film.

Unfortunately, there is little similar data available on the penetration of paint films, and the limited results reproduced in Fig. 3 should not be taken as representative. In this connection it is interesting to note that the spectral reflectivities of paint pigments, given in Table 1, suggest the use of far infra-red wavelengths. In fact, however, a white synthetic enamel may absorb 50 per cent. of near infra-red radiation, and absorption may be as high as 80 per cent. for various colours, approaching 100 per cent. for black. These results seem to indicate effective penetration of the more or less transparent vehicle in which the pigment particles are suspended.

Many materials are characterised by gradually

**TABLE 1.**

**SPECTRAL REFLECTIVITIES OF PIGMENTS.**

(From Smithsonian Physical Tables.)

| PIGMENT. | WAVELENGTH Å | | | |
|---|---|---|---|---|
| | 6,000 | 9 500 | 44,000 | 88,000 |
| $Co_2O_3$ (Steel Grey) ... | 3 | 4 | 14 | 13 |
| $Cr_2O_3$ (Dark Green) ... | 27 | 45 | 33 | 5 |
| PbO (Yellow) ... | 52 | | 51 | 26 |
| $Fe_2O_3$ (Red) ... ... | 26 | 41 | 30 | 4 |
| $PbCrO_4$ (Yellow) ... | 70 | | 41 | 5 |
| ZnO (White)... ... | 82 | 86 | 8 | 3 |
| $PbCO_3$ (White) ... | 88 | 93 | 29 | 10 |

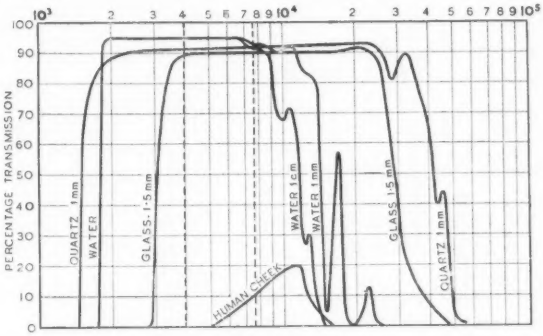
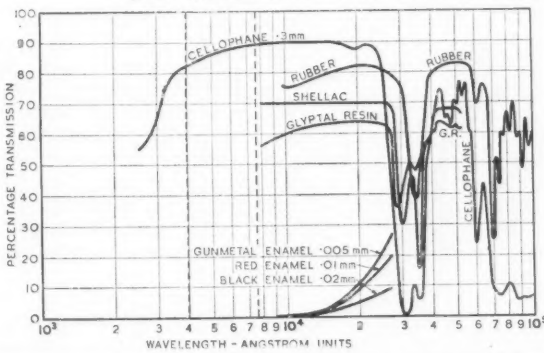



Fig. 3. Spectral Transmissions. *(References 4—11 incl.*




(4) L. S. Ickis and H. Haynes, G.E. Rev., **42,** 145 (1939).
(5) International Critical Tables, **5,** 269.
(6) W. W. Coblentz and R. Stair, B.S.J. Research, **1,** 105, (1928).
(7) W. W. Coblentz and R. Stair, B.S.J. Research, **3,** 629 (1929).
(8) W. M. Powell, Phys. Rev., **46,** 43 (1934).
(9) R. B. Sosman, "Properties of Silica," Chem. Cat. Co. (1927).
(10) Cartwright, J.O.S.A., **20,** 83 (1930).
(11) W. W. Coblentz and R. Stair, B.S.J. Research, **15,** 295 (1935).

varying transmittance or by frequent absorption bands in the infra-red and visible regions; the curves for glyptal resin, shellac, rubber, and cellophane give some idea of these spectral effects. Most substances of this kind have relatively low thermal conductivities, and there are obvious advantages in radiant heating methods based on the absorption of energy during transmission.

To summarise these various considerations there are four factors indicating the general utility of near infra-red and visible wavelengths in radiant heating. Four metals are available for the efficient reflection of visible and infra-red wavelengths—gold, copper, silver, and aluminium. Glass has extreme transparency at *near* infra-red and visible wavelengths, and is suitable for the protective enclosure of practical sources radiating energy in these regions.

Both practical experience, and a study of spectral effects, show that important classes of materials have suitable absorption characteristics at various wavelengths in the near infra-red and visible regions. Relatively fewer of the materials considered have more suitable absorption characteristics at the ultra-violet wavelengths. Energy in this region can be handled efficiently using aluminium and quartz, but the use of this region is not attractive owing to the presence of undesirable spectral effects.

Hence, the infra-red and visible wavelengths are generally applicable to radiant heating, and practical materials are available for the efficient control of energy at these wavelengths.

### Need of Data on Spectral Characteristics.

This brief review of spectral characteristics gives some idea of the physical considerations that should form the basis of radiant heating techniques. It also indicates the type of data required.

With bare metals there is no penetration beyond a few wavelengths deep, and spectral reflectivity alone need be considered.

Absorption during transmission is likely to give the most successful result with many other classes of material. In selecting energy wavebands for given materials, or in choosing suitable materials for existing radiant sources, it is essential to have full data on transmission and absorption characteristics Much work remains to be done in determining the spectral characteristics of materials in common use, and the preparation of these data must be regarded as an essential first step in the effective development of radiant heating.

Infra-red therapeutics provide an excellent example of the value of some appreciation of spectral characteristics even when the physics of the processes served are not fully understood. Thus it is well known that the heating of deep bodily tissue is beneficial, and Fig. 3 shows an appreciable penetration of flesh at wavelengths ranging from 5,000 to 15,000 A.U. This region corresponds to the peak radiation of a tungsten filament at about 3,000°K, and yet reputable practitioners frequently recommend the use of the far infra-red radiation from non-luminous radiators. There is good reason for believing that body tissue is not again penetrated until the region 80,000 to 500,000 A.U. is reached. For efficiency at these wavelengths, the temperature of the radiator should lie between 87°C. and —213°C. Even at 87°C.—the temperature of a hot water bottle—the amount of energy radiated is extremely small, and common experience confirms that any heating of deep tissue is primarily by the slow process of conduction.([12])

### Development of New Materials.

When the design of practical sources of radiant energy is considered it will be seen that there are important reasons for the acceptance of a certain continuous spectrum, or of energy distributions derived from this. The transmission characteristics of some materials may indicate the use of wavelengths lying outside this spectrum if deep heating is to be achieved.

If alternative materials or sources are not available, the only course open may be the development of new materials. Thus the radiant heating process is likely to be a factor not only influencing the choice of materials for a given purpose, but also providing a fresh incentive in the development of new materials. It is already a factor in the selection of paints for protective finishes. Perhaps the spectral characteristics achieved in filter glasses provide a good example of potentialities in the development of new points.

The possibility of utilising selective reflection should not be overlooked. It is not inconceivable that a material may be chosen or developed to secure the rejection of an unwanted wave-band in the spectrum of a radiant source, and the human skin provides an interesting case. Thus a good tan affords protection from the lethal action of sunlight without causing a marked reduction in the absorption of beneficial solar radiations ([12]).

### Sources of Radiant Energy.

There are very many ways of generating energy in the ultra-violet, visible, and infra-red regions. Widely differing spectral distributions are obtainable, including continuous spectra, bands, and lines. These are found in differing widths and locations, and in various combinations.

Some sources have been extensively developed for every-day use, especially in lighting applications. Many more are firmly established as research tools or have narrow applications. It is clear that the progressive development of radiant processes must involve a careful survey of potential radiators, and it has been indicated that there should be co-ordination in the development of new materials and of new sources. This, however, is a matter of future perfection or of the development of special applications.

Under war conditions, speculation in this direction must give way to a consideration of the extent to which substantial advantages can be obtained with equipment already available. Present-day practice is concerned primarily with the heating of paint and water films, similar partly transmitting materials,

(12) M. Luckiesh, "Artificial Sunlight," D. Van Nostrand Co. (1930).

and iron or steel sheets. The characteristics of these materials may suggest the use of differing spectra, but practical experience has shown that the overlapping continuous spectrum of a filament lamp can be applied very successfully to these various substances.

It is a most fortunate circumstance that this source can be utilised so widely, because the filament lamp offers other practical advantages of outstanding importance. For the purposes discussed in this paper, no practical source provides a sufficient concentration of energy in the ultra-violet or in the far infra-red regions. Some sources have attractive spectral distributions, but are too large and diffuse for the amount of energy radiated. Others, such as the carbon or metallic arc, are compact and powerful, but are not available in a simple and convenient form.

A study of the factors involved in designing equipment will emphasise the standard of general utility set by the filament lamp.

### The Tungsten Filament Lamp as an Infra-Red Source.

Factors influencing the design of filament lamps are conveniently illustrated by reference to the radiation characteristics of black bodies. The radiation from a black body is determined by temperature, as shown in Fig. 4, and practical incandescent sources behave in a similar manner. These curves are for bodies of equal size, and the areas beneath the curves are proportional to the total energy radiated at the various temperatures.

Two important effects should be noted. With increasing source temperature, the total radiation increases rapidly, and more energy is radiated at all wavelengths. The second effect is a shift in energy distribution, which brings a still higher percentage of the total energy into the visible and near infra-red regions.

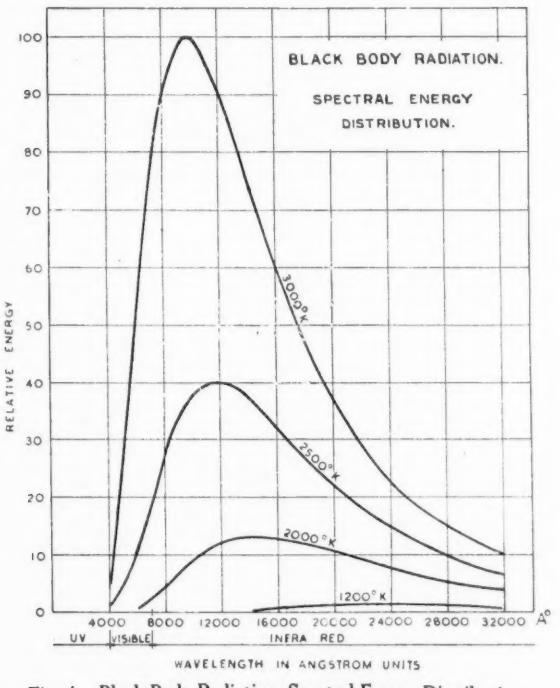



Fig. 4. Black Body Radiation, Spectral Energy Distribution.

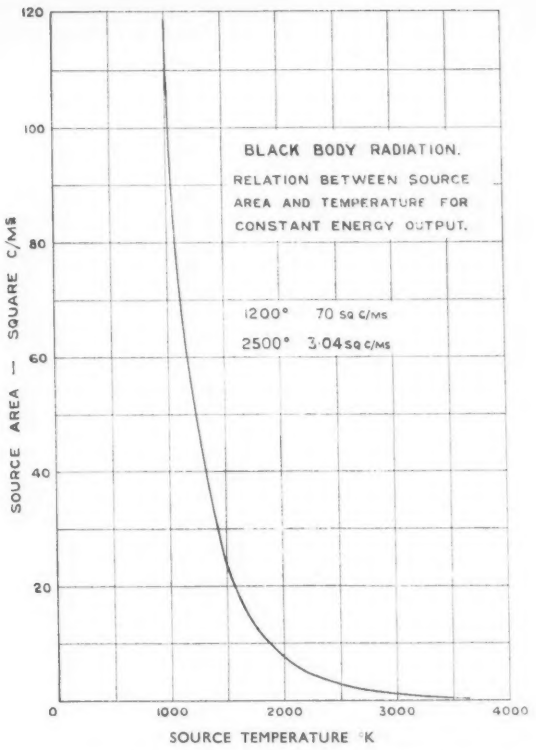



Fig. 5. Black Body Radiation; Relation between Source Area and Temperature for Constant Energy Output.

When maximum energy is required in the visible region, the highest practicable temperatures are adopted. Filament temperatures in the neighbourhood of 3,000°K are usually dictated by the need for a compromise between the efficiency of light production and the life of the source. Similar economic considerations determine a source temperature of about 2,500°K for the "infra-red" lamp. A practical 250-watt infra-red radiator designed on this basis is shown in Fig. 6, and Fig. 7 gives the spectral energy distribution of a typical lamp.

The practical advantages of this form of radiator are due to the enclosed construction. This permits operation of the filament at high temperatures, and makes it possible to obtain increased energy from a compact source. Dependent upon this are both efficient utilisation and the high concentrations of energy required in practical equipment.

Radiators exposed to air, such as the wire element of the domestic heater, cannot be operated normally at temperatures in excess of about 1,200°K. The significance of a change in temperature from 1,200°K to

2,500 K is shown in Fig. 4 and is made clearer by Fig. 5. These figures also give some idea of the relatively negligible amounts of radiant energy available at 360 K and 60 K—that is, for bodies radiating maximum energy in the region of 80,000 to 500,000 A.U.

Besides rendering high temperature operation feasible, the glass jacket has an important effect upon the overall efficiency of the source. With open wire elements a high percentage of the power input is dissipated by convection, and only some 40 to 50 per cent. may be converted into radiant energy, as compared with 80 to 90 per cent. for the infra-red lamps.

### Spectral Suitability of Infra-Red Filament Lamps.

Electrical energy is very efficiently converted into radiant energy by the filament lamp, but the overall efficiency of a heat process rests on two further factors—efficiency in directing energy to the work, and effective absorption by the work.

In so far as spectral distribution affects the efficient control of energy, Fig. 8 shows the providential manner in which the lamp distribution fits the characteristics of the engineering materials available. The great bulk of the radiation lies between the limits of efficient control, set by reflecting surfaces at the shorter wavelengths, and by protective cover glasses at the longer. The achievement of a high utilisation factor is therefore a matter of apt equipment design.

Effective absorption may be realised in more ways than one. A high percentage of the incident energy is actually absorbed in paint baking, and figures of

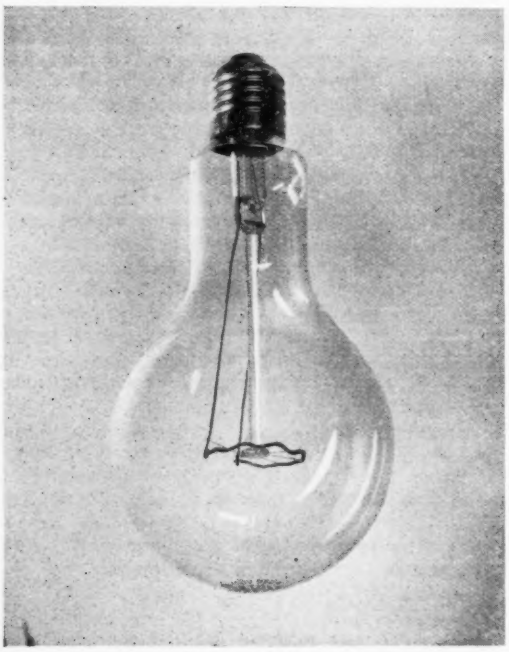


Fig. 6. 250 watt Infra-red Lamp.

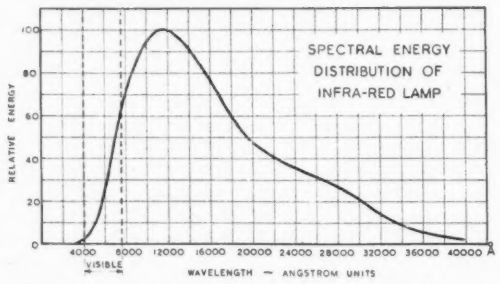



Fig. 7. Spectral Energy Distribution of Infra-red Lamp.

50 to 90 per cent. are obtained in practice, depending upon colour.

Per cent. absorption is by no means the only criterion, and the manner of absorption may be equally or more important. Thus if a thin film of semi-transparent material is quickly and successfully treated by absorption during transmission, it is probably unimportant that a proportion of the energy penetrates completely and is lost. Fig. 3 indicates that the lamp distribution is well suited to the deep heating of materials in common use.

In this respect, and in other ways, radiant energy often provides the most effective means of releasing heat where it will have the most immediate effect. By the instant transference of heat to the seat of operation, processing times are drastically cut.

Thus the main value of radiant heating, as also the overall efficiency of the process, arises largely from reduction in process time. To this end effective absorption of energy means the release of heat at the most suitable point rather than a high utilisation of the total energy provided.

Experience of widely differing applications in the United States has provided evidence of the suitability of the lamp distribution on this basis.([4, 13]) Similar spectral distributions have been applied successfully to paint baking on a large scale; the drying of spirit lacquers and varnishes on metal foils, pencils,

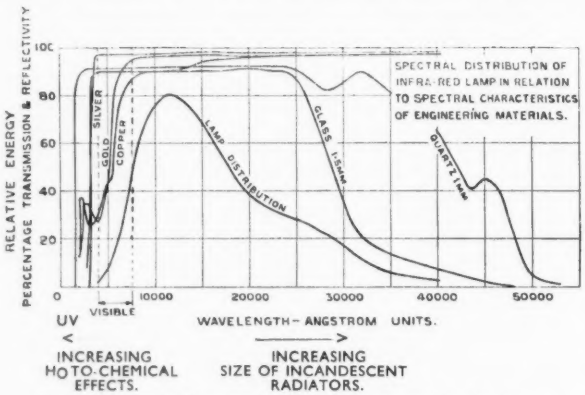



Fig. 8. Spectral Distribution of Infra-red Lamp in relation to Spectral Characteristics of Engineering Materials.

(13) H. Haynes, I.E.S. Trans. (Am.), Jan. 1941.

and various materials; the drying of inks on various materials ranging from paper and cellophane to metals; the softening of thermo-plastics; the de-hydration of plywood, and similar materials including carpets; the drying of photographic films and of Latex; the evaporation of water from blue prints and from the surfaces of metals; and the pre-heating of various metal parts such as engine pistons.

The application of such sources is not so far advanced in this country, but in the author's experience the advantages in paint baking are confirmed, and experimental investigations show promise in many directions.

Paint baking is by far the most generally significant application in war-time, and it is a process requiring effective utilisation of the radiation both in the percentage and in the manner of absorption.

### Paint Baking with Near Infra-Red Energy.

A reduction in the baking time from hours to minutes is often claimed for infra-red equipment. There is no doubt that, on a very fair basis of comparison, reduction from 60 to 5 or 6 minutes may be accepted as common. In some cases the convection method is more favourably placed; in others, the advantages of the radiant method are even more pronounced. Saving in time is but one of the practical gains, and, in addition, there is usually evidence of more perfect baking.

When such results were first obtained, they were frequently attributed to some catalytic or direct action of the radiation. The author's colleagues demonstrated in 1935 that this was not an explanation. Thus identical enamelled steel sheets were heated by irradiating in one case the painted face, and in the other the back surface. Similar results were obtained at similar baking temperatures.

The explanation is apparently supplied in part by Fig. 9. When a paint is said to be stoved at 320° F. for one hour, the article is in fact placed in air at

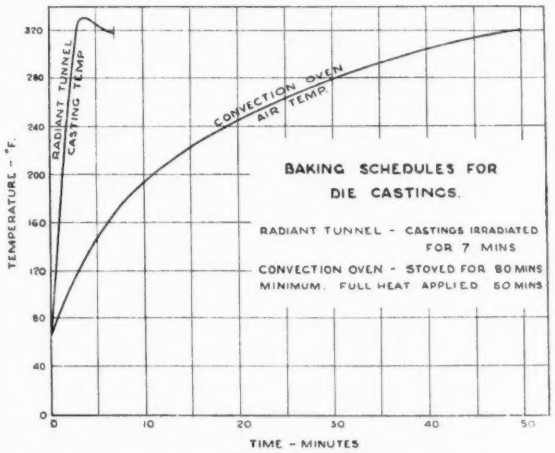



Fig. 9. Comparison of Temperature Cycles in Radiant and Convection Equipment.

320° for one hour, and may not actually attain that temperature at all. In radiant heating, temperatures quoted are actually those measured on the work, since the surrounding air is necessarily about room temperature. From this it appears that with certain enamels the necessary structural changes can be effected in two to three minutes *at appropriate temperatures*, and such temperatures can often be obtained in one to three minutes by radiant heating.

In realising such results in practice, it is, of course, necessary to select suitable paints and enamels. The structural change required in the paint must be one which can, in fact, be successfully accomplished very rapidly. From the "drying" or "baking" standpoint, paint finishes may be divided roughly into three groups—lacquers, synthetics, and oleo resins—and different changes or combinations of changes are involved. In general, lacquers "dry" by the evaporation of solvents; synthetics reach their final state by evaporation and polymerisation; and oleoresins by evaporation, polymerisation, and oxidation. The times normally taken to complete these processes depend on many factors in paint chemistry, and range from several minutes in air for some lacquers to several hours in a convection oven for oleoresins. Paints of all classes can be processed more rapidly by radiant heating. Even some oleoresins may be dried in fifteen to twenty minutes, and here speed is limited by the time required for the extensive oxidation of oils.

The fuller potentialities of the infra-red process are realised, however, with some "synthetics"—a remarkable class of materials offering great scope for development. The paint chemist alone is competent to discuss the compounds and chemical changes which may play a part in the production of quick-baking finishes for various purposes. Even so, the layman may glean some idea of the type of transformation involved from a definition of polymerisation. A substance is said to polymerise when it changes into a form having the same elements in the same proportions, but having a higher molecular weight such as would result from the combination of two or more molecules. Thus, the baking of a synthetic is usually accompanied by considerable structural change, and the resulting finish possesses properties differing greatly from those of the original compound.

It is sometimes thought that the "nature" of an enamel may be lost, or the protective properties impaired by the rapid attainment of baking temperatures. In fact, the evidence is in the opposite direction, and it is generally found that both evaporation and polymerisation are more complete, especially *deeper* in the paint film. This result seems to indicate appreciable penetration by the energy and effective deep heating. If heating were mainly superficial, the formation of a surface skin would be expected, with a consequent trapping of volatiles. Thus, the toughest films can be expected only from deep heating applied rapidly enough for volatiles to be driven off before a surface skin can form.

It is clear that much depends upon the characteristics of the paint. It must be capable of receiving

and transmitting energy at a high rate for the rapid heating of the entire article—usually of metal —and of doing this without excessive surface temperature.

The full development of this application obviously calls for the close collaboration of the paint chemist and the engineer, both of whom must appreciate something of the other's problems. The results of collaboration should be enamels suited structurally to rapid baking and spectrally to the radiant sources available. Permissible baking temperatures and temperature gradients are the data required by the engineer as a basis of equipment design.

### Engineering Principles and Practice.

Underlying the design of equipment are general principles closely resembling those familiar to lighting engineers. As in lighting practice, the design objective and the performance of equipment are both conveniently stated in terms of flux density at a working plane. Table 2 shows a comparison of units of measurements for the two purposes.

**TABLE 2.**

| Measurement. | Symbol. | Radiant Energy Unit. | Luminous Energy Unit. |
|---|---|---|---|
| Flux ... | $\phi$ | Watt | Lumen |
| Flux Density ... | $E = \frac{d\phi}{dA}$ | Watt/sq. in. | Lumen/sq. ft. (foot-candle) |
| Energy ... | $U = \phi dt$ | Watt-sec. (Joule) | Lumen-sec. |
| Intensity ... | $I = \frac{d\phi}{d\omega}$ | Watt per Steradian | Lumen per Steradian (Candle) |

In radiant heating problems, the unit of intensity is of more use in the calibration of instruments than in the design of installations. Thus, concentrating reflectors of 5″ to 12″ diameter are commonly applied at distances of 15″ to 30″ from the working plane, and the inverse square law does not apply.

Where parabolic reflectors are applied to plane surfaces, installation design is relatively simple. In more complex installations, flux density calculations may perhaps be dealt with on an empirical basis somewhat reminiscent of the method used in arriving at average room illumination. This condition arises not only from the dimensions of radiating systems. It is due also to the complex reflection of energy between reflector banks, and between reflectors and the surfaces treated.

In large tunnels using parabolic reflectors, the end surfaces of articles are heated by the direct radiation from a number of the lamps. Reflectors having ellipsoidal and other profiles are also used, both for the control of end radiation and for the concentration of energy. It is seen that the representation of reflector performance presents new problems.

As in lighting, the engineering problem has four main aspects—the measurement of energy, the determination of flux density required, the design of reflectors, and the planning of installations.

Fig. 10. Experimental Vacuum Thermo-couple used in Measurements of Total Radiation.

### Measurement of Energy.

In the practice now under consideration, the energy applied has a substantially fixed spectral distribution. It is therefore satisfactory to determine flux densities by the measurement of total radiation, and two classes of instruments are of practical interest.

The bolometer depends upon the change in resistance of a receiving element forming one arm of a Wheatstone bridge. A high sensitivity is achieved by using a receiving element of low thermal capacity.

The thermo-couple is the basic element in radiometers and thermopiles. The radiometer consists of a thermal junction built into the moving coil of a galvanometer. It is very sensitive, but is not of general utility. The thermopile achieves sensitivity by the combination of a number of thermo-couples, the hot junctions being brought together under thin blackened discs. For compactness the cold junctions may be located in the same housing, but in prolonged operation at high densities this arrangement results in a zero drift as the housing temperature rises. With the cold junctions removed to a distance the instrument is, of course, less convenient.

The vacuum thermo-couple is a convenient practical instrument, and Fig. 10 shows an experimental form. The hot junction is formed between strips of foil approximately one micron thick, and is blackened on the receiving side. With the cold junction formed inside the bulb, the zero drift may reach 8 per cent. after prolonged operation. For appreciable periods, however, the drift is very small with a suitable design. Used with a 240 micro-amp. meter this instrument has a very quick response and good sensitivity. With a meter resistance of 9 ohms, a full scale reading is obtained at a flux density of 2.0 watts/sq. inch. The instrument shown in Fig. 10 has been developed by the author's colleague, Mr. J. N.

Hull. An instrument designed on the same principle has been described by Stack (14).

The thermopile and the vacuum thermo-couple are both useful practical instruments, and the choice of one or the other depends mainly on the particular use in view. Thus the glass enclosure of the vacuum thermo-couple will absorb the longer infra-red radiation, whereas the thermopile can be designed to avoid this effect.

In blackening the receiving surfaces of all these instruments, it is important to use a material having a uniform response at visible and infra-red wavelengths. Soot becomes transparent with increasing wavelengths, and a film which is opaque to visible radiation may have a transmission of 15 to 20 per cent. at 30,000 A.U. A thin layer of zinc black is very suitable, and will absorb about 98 per cent. of the incident radiation at wavelengths between the ultra-violet and 140,000 A.U. (15).

When measurements of total radiation are used in defining incident energy, it is necessary to bear in mind that a fixed spectral energy distribution is assumed. It should not be forgotten that the lamp distribution may be modified by the spectral reflectivities and transmission of materials used in the design of practical equipment. Furthermore, the materials heated may reradiate energy at longer wavelengths, and this energy may be returned by the reflectors to the working plane.

The temperatures actually attained in the materials treated are most conveniently measured with thermo-couples. Two necessary precautions may be mentioned. The thermo junction itself should be protected from radiation or it may assume a temperature differing from that of the material. The method of attachment should not cause local cooling of the material, which may arise either from obstruction of radiation or from heat conduction by the couple. Both requirements present obvious difficulties in the determination of temperature in paint films, since the material is more or less transparent and has a low thermal conductivity. For practical purposes it would seem best to record the temperatures attained in the underlying metal, and to correlate these with the results obtained at known paint temperatures. There may, of course, be significant temperature gradients in the metal, especially if the article is of appreciable thickness.

### The Determination of Flux Densities Required.

The baking of an enamelled metal sheet may be taken as an illustration of the factors involved in determining suitable flux densities.

It is known that the baking of an enamel may be completed in two to four minutes at an appropriate temperature—say 300° F. It is important to attain this temperature in a similar time interval, preferably less. Hence a steep temperature gradient is the aim, and a relatively high rate of heat transference is required.

The heat quantities to be transferred in attaining temperature are determined by the mass and specific heat of the steel, and by the increasing dissipation and utilisation of energy as the temperature rises. The flux density required for a given rate of heat transference depends upon the percentage absorption and area of the receiving surface. Hence the factors involved are:—

- Temperature gradient required.
- Mass and specific heat of metal.
- Heat for evaporation of volatiles.
- Rate of heat dissipation.
- Area of receiving surface.
- Characteristics of absorbing material.
- Incident flux density.

The maintenance of temperature is a matter of supplying only the energy required for evaporation of volatiles and structural change and the heat dissipation. The factors involved are:—

- Heat required for paint baking.
- Reradiation of energy.
- Convection and conduction losses.

Where a steep temperature gradient is attempted the flux density should be reduced for the maintenance of temperature, or the enamel may be damaged by excessive temperature.

In the case of metal sheets of uniform thickness useful data relating these factors may be determined experimentally, and represented in curves such as those of Figs. 11 and 12. Fig. 11 demonstrates well the influence of the ratio of mass to area, and Fig. 12 shows the effect of absorption characteristics.

It should be noted that such data are not universally applicable, since some of the conditions of test are unlikely to be repeated exactly. For example, the rate of heat dissipation can only be predicted, since it will vary with installation design and with the shape of the article treated.

Thus, from experience of installations and from experimental data on materials, it is possible to estimate flux densities to give a desired temperature

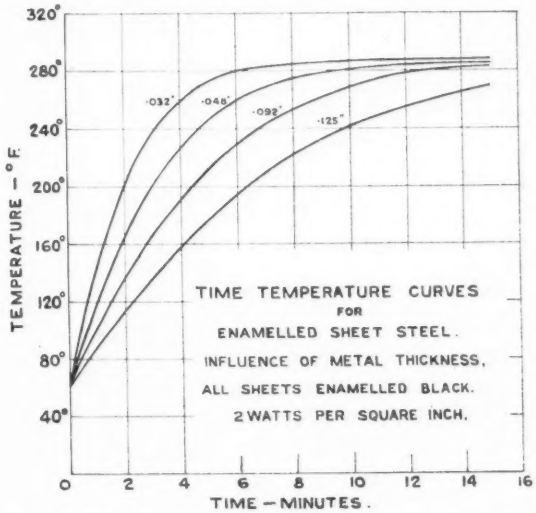



Fig. 11. Time-Temperature Curves for Enamelled Sheet Steel, showing influence of thickness of metal.

(14) S. S. Stack, G.E. Rev., **42**, 365 (1939).
(15) W. E. Forsythe, "Measurement of Radiant Energy," McGraw Hill (1937).

gradient, or to maintain various temperatures. When these are used in the design of an installation, however, it is usually necessary to set up an experimental section and check results. In this way the preliminary estimate is corrected to allow for conditions

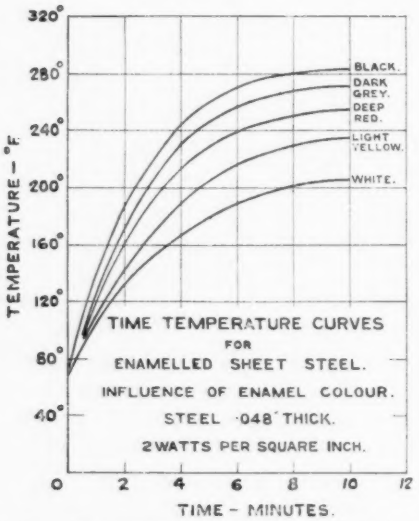



Fig. 12. Time Temperature Curves for Enamelled Sheet Steel, showing influence of Enamel Colour.

peculiar to the installation and to the article treated. This does not mean that an installation need have a narrow application, and this point is further discussed in relation to the design of installation. Flux densities may range between 0.5 and 10 watts/sq. in. in practice, and densities of 2 to 3 watts/sq. in. are widely used.

### Reflector Design.

Reflector distribution is closely linked with the design of installation, and parabolic, ellipsoidal, and special profiles are all used.

In most applications there is one factor applying to all types. Thus, reflectors are often arranged in close honeycomb formation for the irradiation of a

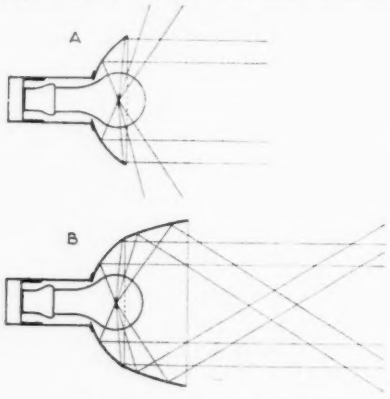



Fig. 13. Types of Reflector.

surface about 15 in. from the reflector mouths. It is clear that the number of reflectors in a given area will vary inversely with the square of the reflector diameter. The maximum flux density obtainable in such installations therefore depends on the reflector dimensions for a given power of source, as well as on reflector efficiency. This emphasises the need for compact sources if high utilisation factors and desired flux distribution are to be obtained.

For parabolic profiles of fixed diameter the beam flux density is proportional to the angle of collection. In many applications, however, lateral radiation is also required, and this factor sets a limit to reflector cut-off and to the angle of collection. The form of reflector distribution is determined by the balance required between normal and lateral radiation, and this depends upon the method of applying reflectors in an installation.

Special profiles may be required to meet various requirements, and one such form is shown in Fig. 13.

The representation of flux distribution presents difficulties due to the relatively small dimensions of the installation. The performance of a parabolic reflector may be represented by data on the uniformity of flux density in the parallel beam, together with a polar curve showing direct radiation from the source. More complex reflector designs do not lend themselves to so direct a method, and it may be that either the profile itself or a polar curve taken in the normal way are equally suitable for record purposes.

The choice of reflector surface depends upon special problems of chemical stability and maintenance as well as upon reflectivity. The efficiencies of gold, copper, silver, and anodised aluminium are all sufficiently high for practical considerations to be the determining factor. Although anodised aluminium is less efficient initially than the other metals, it is very resistant and durable. Copper and silver both tarnish rapidly, and practical means of protecting these metals are not as effective as anodising is with aluminium. Gold is very stable in many industrial atmospheres, and solids deposited on the reflector during the volatilisation of paint thinners can be removed by chemicals without damage to the reflector surface. The practical choice, therefore, lies mainly between gold and anodised aluminium and would normally be decided by the nature of the work handled or by economic considerations. Under present conditions the choice is, of course, narrowed to gold.

Slightly diffiusing cover glasses may be needed in some applications to prevent striation and consequent uneven heating. Diffusion is seldom required where there is relative movement between the reflectors and the work, but plain cover glasses may be an advantage in protecting the reflecting surface from drips and vapours in some applications. Filters may also be used as cover glasses where there is an advantage in suppressing certain wavelengths.

### Installation Design.

Diversity in installation design is well exemplified in the baking of enamelled metal products. The main factors controlling the general form of an installation

are shape of the product, flux densities required, and the method of operation.

Flat banks of reflectors are readily applied to simple flat surfaces and to areas having relatively shallow configurations. More complex articles may be surrounded by reflectors, the normal aim being to produce a substantially uniform flux density over the variously inclined surfaces. Both static and portable equipments may be designed on this basis.

A time-saving process, however, assumes the greatest significance when applied to mass production, and infra-red equipment is most interesting, botn tecnnically and economically, when designed to operate with automatic conveyors. For this purpose installations are usually in the form of straight open-ended tunnels, often circular in cross section, but sometimes shaped to the general outline of a product.

An obvious problem in tunnel design is the projection of flux longitudinally, and this requirement complicates the design of both reflector and tunnel. There is, however, the advantage that the installation is no longer closely linked with the form of the article treated, and a tunnel can be designed for products of differing shape.

Other practical advantages are inherent in the tunnel installation. With work conveyed at constant speed through the tunnel a desired heating cycle is readily achieved by providing different flux densities over consecutive sections. Furthermore, movement of the work relative to the reflectors has the effect of averaging small variations in flux density due, for example, to slight striation in reflector distribution.

Tunnels of circular cross section have wide applications, and parabolic reflectors may be used, as shown in Fig. 14. Relatively high flux densities are produced within the circle "A" by the overlapping beams, and the tunnel diameter is determined by the flux density required. Alternatively, the tunnel may be designed for working planes located in the neighbourhood of circle "B"—that is, approximately 15" from the reflector mouths. Either parabolic or special profiles may be used for this purpose, the flux density being determined by reflector diameter and power of source. Flux densities between 1 and 10 watts/sq. inch are obtainable in tunnels using the 250-watt lamp.

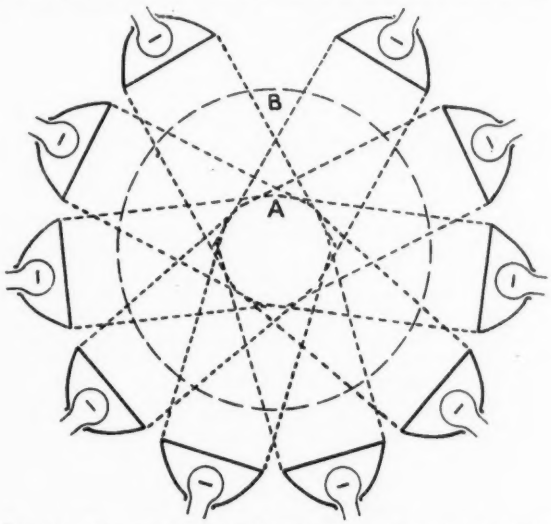



Fig. 14. Section of Circular Tunnel—Methods of using Parabolic Reflectors.

The length of a tunnel is determined by the times required to attain temperature or for subsequent baking, and by the conveyor speed. If the process time is fixed, increased output means higher conveyor speed and longer tunnels.

When tunnels are designed to accommodate various products, the working schedule may require modification in respect of either flux density or process time. The installation must, of course, be designed to give the maximum flux density required, and reduced densities may be provided either by switching out a proportion of the reflectors or by operating the lamps at reduced voltage. Switching is preferable and can be applied if the tunnel has been designed to give the necessary uniformity with the reduced number of sources. Similarly, the tunnel length must be sufficient to give the longer process time with the minimum conveyor speed acceptable. Shorter times are obtainable by switching out sections of a tunnel or by increasing conveyor speed if this is preferred.

### Experimental Determinations.

It is seen that widely differing distributions of flux are dictated by the shape and size of the article and by the method of operation adopted. Different flux densities are also necessitated by the diversity of work—notably in characteristics such as the ratio of mass to area and the absorption factor. Furthermore, the provision of the selected flux distribution and flux densities may involve various principles in the design and application of reflector units.

Extreme versatility is therefore necessary in the design of installations. While a scheme can be resolved broadly from practical and theoretical considerations, the accurate prediction of performance would require much labour, and masses of empirical data. For this reason an experimental set-up is favoured in finalising a proposed design. This procedure provides a means of dealing with complex reflections within the installation, and of basing the design on the actual conditions of interception and re-radiation of energy by the work itself.

Reference has also been made to the fact that the flux densities required by an article are dependent upon the rate of heat dissipation, and are therefore partly determined by installation characteristics. In this connection also an experimental section of a proposed installation provides a means of establishing the exact design objective.

Design methods will no doubt be simplified as practice is standardised and applications are classified. For the present, however, the *final* determination of

both the design objective and the installation design is more quickly and economically reached by experimental investigation. Extensive and flexible laboratory facilities are needed for this purpose, and typical arrangements are shown in Figs. 15 to 18.

### The Modification of Spectral Distribution in Practical Equipments.

In paint-baking installations the spectral energy distribution of the lamp may be modified appreciably by the introduction of energy re-radiated at longer wavelengths by the treated articles as they attain baking temperature. Part of this radiation will be returned to the article by the reflectors of the installation unless it is absorbed by reflector cover glasses. There may also be appreciable re-radiation from the surface of the paint, deeper into the film. It is possible that such re-radiated energy contributes appreciably to the deep heating of finishes which are less transparent at the shorter wavelengths.

Some processes may be improved by the suppression of certain wavelengths. For such purposes the spectral energy distribution of the filament lamp can of course be modified by the absorption of various wavelengths in filter glasses, and these may be applied in the form of reflector cover glasses. Fig. 19 shows the spectral characteristics of a typical filter designed to absorb the shorter visible wavelengths and to transmit high percentages of the near infra-red.

### The Efficiency of Infra-Red Processes.

In the narrower sense of the conservation of energy, infra-red heating has a relatively high efficiency. Some 80 to 90 per cent. of the electrical power imput is transformed into radiant energy, and utilisation

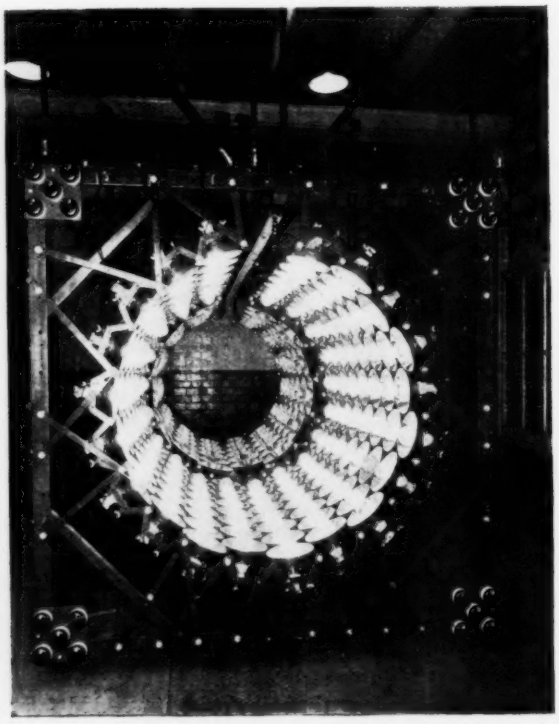


Fig. 15. Experimental Laboratory Tunnel.

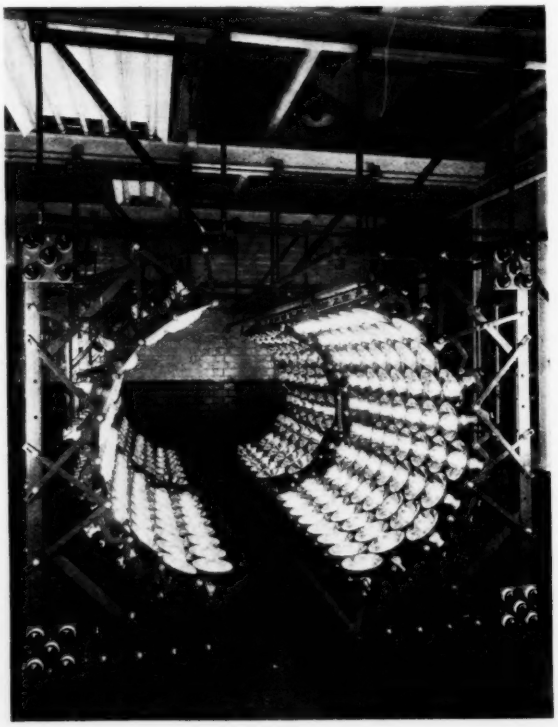


Fig. 16. Circular Tunnel split to give access to Equipment.

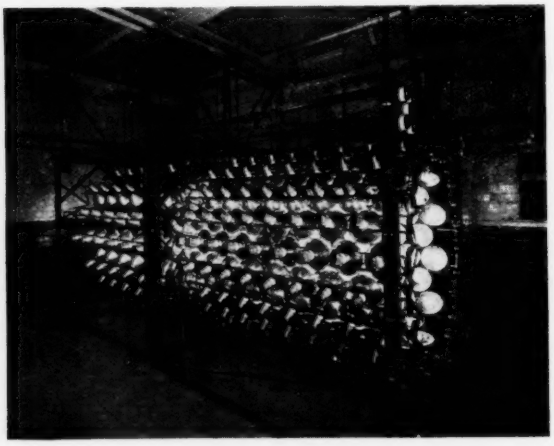


Fig. 17. Part of the Infra-red Laboratory.

factors of 55 to 75 per cent. are generally practicable in applying the energy to a working plane.

Between 50 and 90 per cent. of the incident energy is commonly absorbed in paint-baking applications. Energy not intercepted by the absorbing material, and energy reflected, transmitted or re-radiated by it, is in part returned to the working plane by the reflectors of the heating installation.

Properly conceived and executed, the infra-red process is capable of extremely high efficiency in the still more important sense that desirable results are produced. In some cases there may be no other way of producing the required effect; for example, it has been shown that there *are* special technical potentialities in the release of heat at the most suitable point.

From this characteristic there also arises, in a more general way, a high overall efficiency as measured on the basis of factory economics. Thus the supply of energy is instantly available, and heat appears with equal celerity in the article treated. This immediate release of heat at the very seat of operations results in a striking reduction of process times; in normal operation there is a resultant economy in power consumption and in factory space; furthermore, there is no loss of time or power in operating an intermittent schedule, since there is neither an initial lag nor any storage of heat.

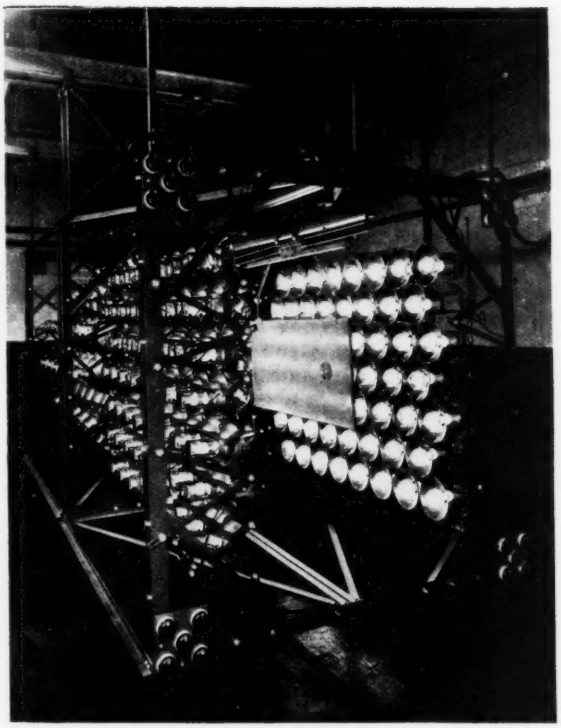


Fig. 18. Experimental Section of Simple Flat Banks.

### The Ventilation of Paint-Baking Tunnels.

Volatiles driven out during the baking of enamels are carried upwards by natural convection currents and are conveniently extracted from above the tunnels. Ventilation materially assists the evaporation of solvents and makes for better working conditions. It is usually desirable, however, to control the ventilation by external baffles so that the dissipation of heat by convection does not reach undue proportions.

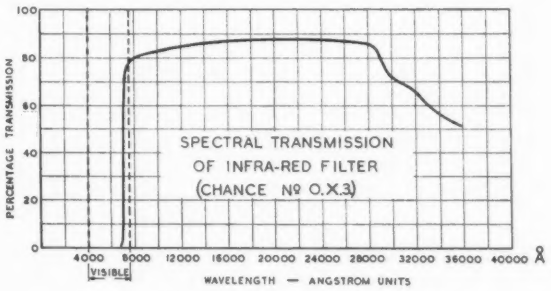



Fig. 19. Spectral Transmission of I.R. Filter.

### Future Development and Standardisation.

In the directions of practical convenience, time saving, and energy conservation, the radiant heating process offers much of immediate value. In addition to these obvious economic advantages, the process has a still more important long-range significance in the attainment of superior qualitative results of which evidence already exists, and in the promise of techniques not approachable by other means. In this respect future development must clearly be guided by a full appreciation of the physical aspects.

For the present choice of the visible and near infra-red wavelengths, good reasons are discernible both in the design of practical sources and equipment, and in the physics of certain processes. In the immediately important field of paint baking, the choice of the near infra-red region appears stable and enduring on the physical score alone. Thus in the deep heating of enamel on steel, it is almost certainly desirable to aim at partial absorption of energy in the enamel during transmission, and part direct absorption in the steel after penetration of the enamel. At the far infra-red wavelengths, enamels will probably be too transparent, and steel is certainly too highly reflecting for adequate absorption of the energy. The near infra-red and visible wavelengths are acceptable for the absorption of energy by steel, and enamels should be developed to suit these wavelengths.

There is therefore every reason to look forward to the advantages of standardisation of near infra-red sources for the baking of enamels, the evaporation of

water, and probably for many other important applications.

**Acknowledgments.**

Mr. J. C. Lowson, Mr. J. N. Hull, and Mr. J. W. Sheldon have been directly concerned in the practical investigations, and Mr. Hull has been of great assistance in the preparation of the physical data for presentation in this paper. The author is glad to express his appreciation of their co-operation.

Acknowledgments are equally due to paint technologists for their invaluable collaboration and advice, and to the author's colleagues, Mr. R. Newbound and Mr. T. Ward, for guidance in matters relating to the chemical characteristics of synthetic enamels and similar materials.

The author wishes to acknowledge the permission of the directors of the B.T.H. Company to publish this paper.

## APPENDIX.

For this paper, an experiment had been prepared showing the penetration of paint film by near infra-red energy. Owing to lack of time, this was demonstrated to only a few members, and a brief description of the experiment is given here.

Thin glass plates were sprayed with enamels of various colours, the thickness of the paint film being between 1 and 1¼ thousandths of an inch. Measurements of the total radiation transmitted by the plates were made with the vacuum thermo-couple shown in Fig. 10, the source of energy being an infra-red lamp of the type shown in Fig 6.

The following table summarises the results:—

| Material. | Relative Reading. |
|---|---|
| Plain glass plate | 100 |
| Black | 4 |
| Green | 11 |
| Blue | 19 |
| Grey | 20 |
| Red | 24 |
| Yellow | 56 |

These results are based on readings taken with the paint film at room temperature. As the temperature of the film rises, a substantially higher reading is obtained, due to the re-radiation of energy. The increased reading is due only to re-radiation, as is readily demonstrated by switching off the irradiating source. The paints used were various types of synthetic enamel.

## DISCUSSION

Mr. O. W. HUMPHREYS said it was quite clear that the subject was one to which Mr. Maxted had given very careful and detailed consideration, and one could clearly see the potentialities of the system for both peacetime and wartime purposes. It was not his intention to say very much directly on the paper. His remarks would be of a more general nature, arising out of the interest he personally had had in the subject for a good many years. He had read most of the extensive literature, and must admit that he had sensed a tendency to endow radiant heating with a sort of mystic air, and to suggest that lamps were chosen as the ideal source of radiation following a careful investigation of the energy distribution curves of various sources and the transmission characteristics of paint, and other films. He was inclined to think that the real story was a little more simple. Probably a production engineer finding paint drying a serious bottle-neck, asked his research department what they could do about it. They soon found that the root of the problem was the long time taken to reach the desired stoving temperature. Very little consideration showed that of the three methods of transferring heat convection was the least effective; and either conduction or radiation would be greatly superior. Conduction was ruled out by practical considerations so they concentrated on devising suitable means of using radiation. It was immediately clear that with this method the atmosphere would not be heated, and consequently no air-tight enclosure would be required. In the absence of such an enclosure the source required enclosing in a transparent envelope to keep down the convection losses from it, and in order that the source might be small, to facilitate control of the radiation by reflectors, and at the same time powerful, a high temperature was necessary. Lamps met all these requirements and so were tried out, found successful, and adopted. Subsequently the possibility that there might be some photo-chemical or similar effect due to the wave-lengths of the energy employed and not directly associated with heat must have occurred to the experimenters. It was possible, of course, that these investigations had progressed further than the literature indicated, but he thought that when fundamental research on matters such as this again became possible there would still be a large field open for exploration. Although he had a first thought that Mr. Maxted was tending to add to the folds of mystery in which the subject had been wrapped, he thought, in considering all that Mr. Maxted had said, that he shared the view that radiant heating was based on expediency rather than the application of any highly developed theory. In connection with reflectors he was somewhat surprised at the continued extensive use of paraboloidal, and similar, reflectors since the use of such reflectors introduced two serious difficulties. Firstly, spacing of the lamps, and consequently the concentration of energy, was controlled by the reflector dimensions, and, secondly, as the field of radiation obtained from these reflectors was circular, or at least never rectangular, there was a tendency towards local concentrations of energy, where the maximum overlapping occurred, and it was difficult to obtain a sufficient uniform distribution for such purposes as the drying of paints or other films on non-conducting surfaces. These limitations could be removed by using a trough reflector in which the lamps could be mounted close together along the axis, thus obtaining both considerably higher density and greater uniformity of radiation on the object heated. As a further development we could use a plain cylindrical tunnel studded with lamps. With such a system exceedingly high concentrations of energy could be obtained. Mr. Humphreys concluded by thanking Mr. Maxted for his paper, to which, he was sure, they had all enjoyed listening.

Mr. G. H. WILLIAMS (I.C.I. Paints) said that one of the most important advantages arising from the application of radiant heat to the drying of paint was that much higher temperatures were obtained than with convection ovens, unless these were specially designed. Even so, limitations were imposed by considerations of cost, and convection ovens capable of producing similar temperatures were expensive. He thought that the short times were due to the high temperatures attainable and that at present the limiting factor was the temperature which the paint would stand without damage. The development of paints to take full advantage of radiant heat drying was a problem for the paint chemist and was already being worked on.

Mr. F. C. SMITH said that he had been greatly interested in Mr. Maxted's work. The saving in time was not the only advantage of infra-red processes. The saving in space possibly resulting from such methods was also an important consideration.

Mr. Smith also inquired, at a later stage in the discussion, whether Mr. Maxted had developed, in practice, any process for the internal drying of articles or whether he relied solely upon the radiant heat being absorbed and thus causing drying from the inside? Had he considered the question of using shaped radiators?

Mr. J. B. CARNE said that in spite of Mr. Maxted's remarks on the subject, and Mr. Humphries' eloquence on the same subject, he still could not be convinced—or, at least, he was still unconvinced—that an electric light bulb was a more efficient source of radiant heat than an exposed filament as used in a domestic electric bowl fire. If the contention was correct that the electric light bulb was more

efficient, then it seemed to him that the radiant heat electric fires that were so numerous at the present time were obsolete in this respect. Were all those people who had electric radiators going to go home and put electric bulbs in place of the electric filament? His own experience was that in some cases an electric filament backed with insulation had a radiant heat efficiency approaching double that of an electric light bulb of the same capacity when fitted in a reflector.

Mr. L. E. BUCKELL remarked that, whilst he did not wish to steal Mr. Maxted's thunder, he would like to remind the last speaker that radiant heat bulbs had been used for heating rooms for something like forty years.

Mr. E. W. MURRAY said he would like to ask Mr. Maxted one or two questions from the physiological and safety points of view. He had been wondering if they were to expect any trouble, first of all in connection with the effects of infra-red on the eyes. Those members who were conversant with welding practice knew that quite a lot of good work had been done by the B.S.I. committee, who prepared the specification for welding glasses. The old glasses (blue and red) did not cut out the infra-red, with the result that there were frequent complaints of headaches, and these were put down to the effects of infra-red radiation. Now, the new glasses made in accordance with the B.S.I. requirements cut out both the infra-red and the ultra-violet radiations. There was also the question of the brightness from these light sources and possible eyestrain. A few years back Sir Leonard Hill raised the question of the inflammation of the nasal mucous membrane which may arise when subjected to the effects of infra-red radiation. In a particular experiment, it was found that, due to the infra-red radiation, the breathing pressure of a person (with some disability) under test went up to five times normal. This meant that that person was expending about twenty-five times the amount of energy in breathing than would have been the case if the infra-red had been neutralised. Further, it was found that the effects of the infra-red can be neutralised when a sufficiency of visible rays are added. It may be that the amount of visible energy from these reflectors quite definitely neutralises the effects of the infra-red. In the process of drying was there going to be any trouble from the possibility of gas and air mixtures causing explosions? Should flame-proof fittings and accessories be used? If some type of extraction plant were designed to dilute the gas and air mixtures, the loss of heat by convection might put up the consumption somewhat.

Dr. A. L. ROBERTS (Department of Coal Gas and Fuel Industries, the University of Leeds) thanked the Society for the invitation to attend that meeting extended to the Gas Research Board, and explained that he was deputising for his colleague, Dr. E. C. W. Smith, the holder of the Arthur Duckham Fellowship of the Institution of Gas Engineers, who was unable to be present owing to indisposition.

He had been greatly interested in Mr. Maxted's authoritative account of the application of infra-red radiation to the drying of paints and varnishes. Dr. Smith and he, and also Mr. D. C. Gunn, of the Yorkshire Industrial Gas Development Centre, had followed the brief descriptions of the American work along these lines which had appeared from time to time; Mr. Maxted's full treatment of the subject was especially welcome, and clearly showed that the process was now well established in this country.

Their own interests extended to the broader field of radiation problems, which included the drying of various materials (for example, heavy clayware), and heat transfer by radiation, which played so important a part in high temperature furnace operation. There seemed no doubt that the application of the principle of selective radiation, i.e., employing radiation over a band of wavelengths which were selectively absorbed by the body to be heated, would provide a means of increasing the efficiency of both heating and drying processes. Such "penetrative" heating of industrial materials was a field which so far appeared to have received little study, and Mr. Maxted's paper was a valuable stimulus to further work.

In all cases, however, a thorough knowledge was required of the emission, absorption, and transmission characteristics of the materials concerned, as Mr. Maxted had emphasised. A research programme embodying such investigations on a wide range of materials had been approved by the Gas Research Board, and a recording infra-red spectrometer had been specially designed for this work.

With regard to sources of infra-red radiation, Mr. Maxted had been concerned solely with the tungsten filament lamp and gold-plated reflector. Dr. Roberts drew attention to the possibilities of gas heated appliances such as the "radiophragm," in which an air-gas mixture was fed through a porous refractory diaphragm to burn on the face. Such appliances presented a large, uniformly heated surface, and allowed some measure of control of the spectral distribution of the radiation.

Mr. E. O. LEMON asked if there was anything very particular in the design and construction of infra-red lamps, and whether it was not a fact that the spectrum of an underrun tungsten filament lamp had the same characteristics as that of an Infra-red lamp; further, whether Infra-red lamps were now available. Since the appearance of certain articles on the subject in the technical Press, he had been endeavouring to find a source of supply of these lamps and reflectors, but so far he had had very little success in that direction.

Mr. H. A. NEWNHAM said the subject of the infra-red drying of paint was a subject that had interested him for some time. First of all, for the benefit of paint users present, from his own experience, he said, it could not be assumed that any paint was suitable for drying by infra-red treatment. As Mr. Maxted had pointed out, one of the most interesting features of infra-red was the rapid rise in temperature which the heated article underwent. This rapid rise in temperature would accelerate each stage of the drying of the paint film. First, the evaporation of the solvent. If the evaporation of the solvent took place at too great a rate one would get surface irregularities in the paint film, and in extreme cases blisters and pinholes. In the case of flat paints, these surface defects were not so obvious, and it might be that it was in flat paints that infra-red would first show its advantages. Secondly, the drying of the paint itself, after the evaporation of the solvent, was accompanied by changes in dimensions, and, if that paint underwent too rapid a drying treatment, once more one got rapid dimensional changes, which would lead to further flaws in the finished film. It is these defects which the paint manufacturer must overcome in designing products for use with infra-red ovens.

Mr. C. E. GREENSLADE mentioned that in very many cases the distribution of light from a given reflector followed very closely the distribution of heat, so that it was often possible, by trial and error, to shape a reflector so as to secure an approach to the desired distribution in this way.

Mr. J. S. Dow (*Communicated*). The subject of Mr. Maxted's paper is a new one to most of us. One may therefore be excused for not understanding some things which are, perhaps, really quite evident. I confess that, like Mr. Carne, I would like a little more explanation of the advantages of using incandescent lamps in preference to elements run at a somewhat lower temperature but open to the air. Is the higher temperature such a definite advantage in drying processes, or does the advantage rest mainly in the concentration of the heat in a small area so that it can be more completely controlled and directed? Is it found that for some processes a lower temperature is preferable, and is the use of open sources therefore still worth consideration for certain drying operations? Does not the fact that the radiation from the filament has to pass through the glass bulb impair efficiency, because we have always been accustomed to regard glass as a protection against the transmission of heat?

Mr. Maxted has shown an interesting diagram showing how different species of radiation are distributed throughout the spectrum with an indication that it is only over a narrow range that absorption takes place. May we take it that physical effects as we experience them are necessarily associated with the absorption of energy, and that in particular heating and drying effects are necessarily associated

with the absorption of energy, and is it a fact that radiation, which produces no sensible impression of heat, may, nevertheless, prove useful for drying purposes? It would give us something to go upon if Mr. Maxted would set approximate limits to the range of wavelengths of any value for drying operations, and if he could tell us anything about the effect of infra-red radiation outside this range.

Mr. S. J. PATMORE (*Communicated*). This new application seems to be another of many examples of processes in connection with which the illuminating engineer can apply to practical purposes the advantages of his specialised scientific training and experience. The list of applications enumerated by Mr. Maxted as having proved successful in the United States takes us but a small way towards the ultimate utilisation of this comparatively new application of lighting technique.

I should be glad if Mr. Maxted would explain in more detail his theory of the advantages of the use of thermo-piles in favour of the vacuum thermo couples. If the glass envelope enclosing the thermo couple absorbs the longer infra-red radiation, surely the same must apply to the glass envelope enclosing the source of radiant energy, i.e., the filament of the infra-red lamp? Mr. Maxted has advocated, in certain cases, the use of a glass screen to protect the surface of the reflector employed with the infra-red lamps. Surely this glass, too, unless of very special characteristics, will also absorb the longer infra-red radiation?

Although my own experience coincides with that of Mr. Maxted in regard to the use of gold plating for reflector surfaces I am wondering if Mr. Maxted could give any figures for the relative efficiencies of rhodium plating and gold—especially in view of the possibility that the use of gold for industrial purposes may prove to be a question of great economic significance after the war.

Apart from their industrial uses it is possible that infra-red units may in future have possibilities for the rapid cooking of eatables—in which connection I recall an amusing experiment involving the baking of jam tarts by means of infra-red equipment in the Wembley canteen. I believe that Mr. Humphreys will be able to endorse the success of this particular experiment.

Mr. R. MAXTED thanked the President for his remarks in opening the discussion.

In reply to the discussion, Mr. Maxted said that, as regards Mr. Humphreys's remarks, he himself had not received the impression that previous investigators abroad had tended to wrap up the subject in mystery. Perhaps certain theories had not been discouraged, but successful practice *had* been established. Had we done the same in this country we should have found the radiant process invaluable in the present war effort. As regards delving deeply into the subject, he thought that cut-and-try successes must be followed up by a careful development of the theory. It was essential to understand the physics of a process if the full potentialities were to be realised in practice. A fuller knowledge enabled one to cultivate the essentials upon which success depends and to recognise those features of earlier practice which had no bearing on the results and may be discarded.

In regard to the origin of infra-red paint baking in this country, in his own knowledge, it was even more direct than had been suggested by Mr. Humphreys. The lamps were simply applied to local heating, and as he had indicated in his paper, the results obtained were so remarkable that some catalytic or direct action of the radiation was suspected. When it was demonstrated that there was no such mysterious explanation of the results, interest faded and it was forgotten that the radiant heat process provided an extremely efficient method of transferring heat. He believed there were people in the audience that day who were concerned with those first experiments in this country some six or seven years ago.

Concerning reflector design, Mr. Humphreys had referred to the limitation of flux density by reflector dimensions. As Mr. Newnham had pointed out, there was a limit to the temperature at which paint could be baked. He thought that the densities available were ample for most purposes. In this country we were as yet dealing with a 250-watt lamp, and there was ample scope to obtain increased density by the use of more powerful sources. In America lamps up to 1,000 watts had been developed, and yet experience had shown that the 250-watt lamps used in circular reflectors were preferred for most applications. On the subject of the uniformity of flux distribution obtainable with circular reflectors he had not experienced any difficulty there. Someone else had referred to visual methods; these, of course, did help one to check up on uniformity quickly. Normally, the honeycomb arrangement of circular reflectors used at a distance of about 15 in. from the work did give a sufficiently uniform distribution when properly designed. He did not see how trough reflectors avoided overlapping.

As regards the measurement of flux densities, they have found the vacuum thermo-couple very valuable indeed owing to the quick response. Thus, with the article in the tunnel, it was possible to measure incident densities at the article with the vacuum thermo-couple. He had used a plate with a normal thermo-couple attached, as suggested by Mr. Humphreys, but the measurement of flux density by temperature gradient was slow, and in any case he felt the plate was a half-way house. In general, it was more satisfactory to place the actual article in the proposed tunnel and to make temperature measurements on the article itself. Just as in the case of the lighting of an empty factory, insertion of the obstructing articles materially alters the distribution in the installation, and the significant measurements were those made with the articles in place.

Mr. Williams had emphasised the fact that higher temperatures were economically attainable in radiant heating, and that the shorter baking times were due to higher temperatures. There was also the great reduction in time to attain baking temperature. He thought it was important that it should be generally realised that paints must be developed for this purpose, as Mr. Williams had pointed out. It was not possible to obtain a satisfactory result simply by roasting any paint.

Mr. Smith had stressed that the saving of time with the infra-red process meant, at the same time, a saving of factory space. From the point of view of factory economics, the advantages of the process all originated in the reduction in time. This was so especially on intermittent service, as the equipment was instantly available for use on switching on. Regarding the baking of internal surfaces, as in the case of a closed box, this was achieved by conduction through the metal since the whole article was raised to baking temperature.

Replying to Mr. Carne, Mr. Maxted pointed out that the enclosure of a source in a glass bulb prevented cooling of the elements by convection currents, and that consequently less power was required to maintain the source at the chosen temperature. The amount of energy radiated by the source was proportional to the fourth power of the temperature. He could not agree that an open-type radiator could be more efficient than the enclosed type.

Mr. Murray referred to the trouble which had been experienced in welding operations, and which was due to the effect of infra-red radiation upon the eyes of operators. Mr. Maxted said he had not heard of any such effect with filament sources, and suggested that the trouble to which Mr. Murray referred might be due to an infra-red image, on the retina, of the very intense welding arc. Referring to Luckiesh's book on "Artificial Sunlight," Mr. Maxted said that the effect of infra-red radiation was widely accepted as beneficial, apparently due to the stimulation of bodily processes above normal, and including the production of a greater flow of blood in capillaries. In his own experience of standing in an infra-red tunnel, and with special reference to the mucous membranes, the radiation caused a pleasant relaxation and soothing of the deep tissues. Personally, he had not experienced the opposite effect referred to by Mr. Murray, and in any event the effect could not be more than that of an ordinary incandescent lamp, of which we had all had lengthy experience. With reference to safety, it must be remembered that there was natural ventilation of the tunnels and that volatiles were carried off quite rapidly by the convection currents and were thus kept dilute. Solvents and thinners were to a great extent evaporated by the time the painted article reached the equipment. Just what regulations might be involved in this country as

regarded inflammable vapours, he did not know, but it did seem to him that the radiant method was safer than the conventional equipment in that there was the ability to ventilate freely and to carry off volatiles quickly.

Expressing appreciation of the very welcome observations of Dr. Roberts, he was afraid he could not say to what extent the far infra-red was efficient in furnace work. It was to be expected that soot would become transparent at the longer wave lengths, but if the energy were being absorbed in steel, one would expect the near infra-red to be preferable because steel was more absorbent at the shorter wave-lengths.

In answer to Mr. Lemon, there were no peculiarities in the construction of the radiators so far as the user was concerned. There were, of course, design and manufacturing problems in the production of infra-red lamps. He believed the lamps could be obtained in the normal way from leading firms of lamp manufacturers.

With regard to Mr. Newnham's point concerning temperature rises, it was of course fully realised that it was essential to work closely with the paint chemist in developing applications.

Replying to Mr. Studholme's question on the use of vitreous enamel reflectors, he considered that this material would not be very satisfactory, and in the practice at present contemplated a specularly reflecting material was required.

Mr. Greenslade had referred to the advantages of an infra-red source which also radiated some visible energy. He agreed that this enabled one to check the uniformity of flux distribution visually.

*Added*: In reply to Mr. Dow, the paper shows that the incandescent lamp is approximately twice as efficient as an open element on the basis of energy radiated in watts to power input in watts, and that the smaller dimensions of the high temperature source permit of more efficient control and a higher utilisation of the radiant energy. Fig. 4 shows that the total energy radiated by a source increases rapidly with the temperature of a source; hence the maximum flux density obtainable from any arrangement of sources is limited only by source temperature. Fig. 5 shows the way in which source dimensions for a given output are reduced with increasing temperature. The high efficiency of the lamp, as compared with the open elements, in the conversion of electrical energy to radiant energy, is due to the prevention of convection losses from the radiating element.

The study of the physical aspect of the subject shows that the spectral distribution of energy of the lamp is well suited to the deep heating of typical materials having a low thermal conductivity and that it probably represents the best compromise for the heating of both synthetic enamels and the sheet iron or steel upon which these are most commonly applied. Lower temperature sources produce the bulk of their radiation at longer wave-lengths, and this may be preferable for some materials. The practical difficulty is that the lower source temperature limits the total energy and the maximum flux densities available in practical equipment. The high temperature source radiates more energy at *all* wavelengths from a given area of source. Fig. 8 demonstrates how specially well suited the energy distribution of the lamp is from the practical viewpoint, and both theoretical studies and practical experience confirms the value of the near infra-red radiation from a standpoint of the physics of processes.

Referring to the transmission of glass, Fig. 8 shows that the bulk of the radiation from the filament lamp is transmitted by ordinary glass, especially of the thickness commonly used in lamp bulbs. Only the far infra-red radiation, forming the bulk of the energy radiated by lower temperature sources, is absorbed by ordinary glass, and special filter glasses (such as Calorex) must be used to suppress the near infra-red radiation.

Energy at all wave-lengths is absorbed to some extent by all materials, and utilisation of energy for all spectral effects, including heating, is dependent upon absorption. The wave-lengths best suited to the heating depend upon the spectral characteristics of the material. It so happens that the materials in common use are characterised by high absorption of radiant energy at wave-lengths between the extreme ultra-violet and the far infra-red, and the production of heat is the most common result of this absorption. The near infra-red is valuable because undesirable spectral effects are absent and radiation at these wave-lengths is conveniently and efficiently produced and controlled. Wave-lengths which give no sensation of heat to the human body are those at which the body is relatively transparent, the absorption of energy being therefore very low. For example, the presence of energy at radio frequencies is often detected by holding in the closed hand a piece of metal which rapidly heats up due to the absorption of the radiation penetrating the flesh. Radio frequencies are, of course, used in industrial heating as, for example, in the heating of the metal parts of a radio valve for the purpose of driving out occluded gases. I have endeavoured to show in the paper that widely differing wave-lengths are of value from the physical standpoint and that the practical consideration of generating and applying the radiation determines the choice of wavelengths for various applications. It is fortunate that the near infra-red radiation, which is so convenient in practice, is so well suited to many classes of material requiring heating in industry. Thus standardised equipment may be applied to many industrial purposes.

In reply to Mr. Patmore. As shown in Fig. 8, the bulk of the energy radiated by the lamp filament is at wavelengths which are transmitted efficiently by glass, especially of the thickness used in lamp bulbs. This is further proven by the fact that 80 to 90 per cent. of the electrical energy input to the lamp emerges from the bulb as radiant energy with the distribution shown in Fig. 7.

Hence the vacuum thermo-couple is entirely suitable for exploring the density and uniformity of energy reaching the work from the lamp under operating conditions, and for this purpose the quick response of the instrument gives it a notable advantage. Longer wave energy found in an installation is due to re-radiation from the articles heated and does not originate in the lamp. The influence of re-radiated longer wave energy returned to the working plane by the reflectors will depend entirely on the ability of the article to re-absorb the wavelength, and the effect is obviously best checked by temperature measurements of the actual article during treatment. The use of cover glasses, and the type of glass to be used, depend upon the utility of various wavelengths in any application.

The relative efficiencies of gold and rhodium are shown in Fig. 2. As stated in the paper, anodised aluminium has much to recommend it for post-war use.

*Added*: Since presenting this paper, I have felt that a brief survey of the history of the infra-red paint baking process would have been helpful. In preparing the paper I found myself in the difficulty of not wishing to emphasise peace-time applications by a more extensive quotation of American practice, and yet not free to give details of war-time development and potential applications in this country. It is, of course, well known that the paint baking application was established in the United States about 1933. The original work was carried out in the Ford factories on car bodies, and the wider use of the process in more recent years has been well documented by articles in the American technical press.

In this country, early experimental work of which I am aware was also concerned with the stoving of car bodies. My colleagues designed experimental equipment for this application in 1935-36, using incandescent lamps. Published reference to this early work was contained in Mr. Warren's Annual Lecture before the Institution of Electrical Engineers, May 3, 1940, on "Insulation." It is interesting to note that these early equipments made use of trough reflectors such as were suggested by Mr. Humphreys in the discussion on this paper.

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*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."*

## I.E.S. Fellowship.

The following applications for Fellowship have been accepted by the Council:—

Hartill, P. .....Bridge House, Wombourn, WOLVERHAMPTON.
Henshaw, J. M. .....167a, St. Vincent Street, GLASGOW, C2.
Hulcoop, F. A. .....25, Headway, Shirley, SURREY.
Lappin, T. M. .....1, Lochee Road, DUNDEE.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members*:

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Baker, A. C. .....1, Broadmead, BRISTOL, 1.
Bampton, F. L. .....7, Minshull Street, MANCHESTER.
Boucher, F. S. .....312, Deansgate, MANCHESTER, 3.
Bowler, W. C. .....The Brow, Bannerdown Hill, Batheaston, BATH.
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Garner, W. ....."High Toft," Menston - in - Wharfdale, Nr. LEEDS.
Hayward, A. E. ....."Penhawgar," The Hollow, BATH.
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Jones, J. Trevor .....Wordsley, Bargoed, GLAM.
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# PLANNING FOR DAYLIGHT

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## ABSTRACT.

This paper summarises the progress which has been made during recent years, particularly as regards the predetermination of daylight factors and international agreement on a standard of inadequacy for daylighting. The use of the "no-sky line" as a measure of inadequacy is described.

In planning for such buildings as large blocks of offices or multiple dwellings in built-up areas, it is pointed out that there are two fundamental matters to be considered, viz., the drafting of building regulations to secure a share of daylight for every building in the area and the designing of buildings to make the best use of this daylight. The development of an island site on a cruciform plan possesses considerable advantage from the point of view of daylight. Windows must be of adequate height. The access of direct sunlight to buildings is of great importance and the erection of balconies immediately above window heads should be avoided. The paper concludes with a series of recommendations.

### Introduction.

Most people like daylight. There are, of course, advocates of the windowless building; this paper will be of no interest to them. Further, no attempt will be made to enumerate or discuss the beneficial effects of daylight; these will be taken for granted. An excellent résumé of them will be found in a publication of the Health Organisation of the League of Nations.*

The present paper is written, frankly, for those who enjoy daylight, and as much of it as can be secured without disproportionate sacrifices of other amenities. It is written in the faith that those who are to be responsible for the vast programme of post-war building will be anxious to avoid the mistakes of the past and to take full advantage of the very considerable advances in our knowledge of the subject, most of them made within the last few decades. It must be emphasised that the views expressed in the paper are put forward by the author solely on his own responsibility. It is hoped that they will prove to be provocative and will encourage a free expression of opinion from as many as possible of those who are interested in the subject.

There is an awful permanence about the natural lighting of a building. In the case of artificial lighting, as advances are made, out-of-date systems can be changed or replaced without undue expense, but natural lighting is, to all intents and purposes, unchangeable; it is there for the life of the building. In the case of buildings of a "permanent" character, this can be a very serious handicap, and to-day we are surrounded with very expensive and solidly constructed buildings in which the natural lighting can only be described as deplorable. This is a state of affairs which only time can remedy, but in what follows it will be assumed that the architect and town-planning expert have a comparatively free hand and can make use of all the knowledge at present available to them, in daylighting as in every other aspect of their work.

### Recent Progress.

What, then, are the chief directions in which, during the last thirty or forty years, advances have been made in the science and practice of daylight engineering? Although they will naturally be familiar to many members of this Society, it is convenient to summarise them briefly at this stage. First and foremost there has been the gradual acceptance of the daylight factor as a measure of daylight, and to-day it is almost universally employed and understood by those engaged in the design of buildings. Alongside this has grown an acceptance of a particular value of daylight factor as a measure, not so much of adequacy as of the stage at which daylighting becomes really unacceptable to reasonable people. This value has been appropriately termed the "grumble point."*

The position has been crystallised in decisions of the International Commission on Illumination taken in 1928 and 1931.† The former registers general agreement on the principle of the use of a daylight factor to express the value of the daylight at any point in a room, while the latter is more detailed, and the first two parts of it may conveniently be quoted in in full, as follows:—

> "(1) The use of curves of equal daylight factor is recommended for general adoption as a practical method of appraising daylight in all studies concerning the method, the amount, and the efficiency of the daylighting of interiors.
>
> "(2) It is recommended that in all parts of a room in which the daylight factor at table height (85 cm.) is less than 0.2 per cent., the daylight shall be considered as definitely insufficient for carrying on work necessitating visual acuity for any considerable time, work such as

* Bulletin, Vol. VII., pp. 581-607, 1938, "Insolation and Natural and Artificial Lighting in Relation to Housing and Town Planning."

* This term was apparently first employed by Mr. P. J. Waldram in a paper read before this Society. (Illum. Eng., Vol. 16, 1923, p. 96.)

† Commission Int. de l'Eclairage. Compte Rendu des Séances, 1928, p. 12, and 1931, p. 18.

writing. The limit stated should not be regarded as a recommended value of daylight."

The other direction in which a great deal of valuable work has been done is in the development of methods of calculating daylight factors from the geometry of a building. It is now possible, from a knowledge of the dimensions of a room and the design of its fenestration, combined with data regarding any external obstructions visible from inside the room through the window apertures, to make a precise calculation of the daylight factor at any point in the room.

It will be clear that this is a very great advance, since it means that the daylighting in a building can now be predetermined while the building is still on the drawing-board. This paper is not the place to describe the methods which have been developed for this work. Such descriptions will be found in literature already published.* All that it is necessary to do here is to emphasise the fact that there is now no excuse for bad daylighting in new buildings except ignorance, incompetence, or *force majeure* in some form or another.

One of the most common examples of *force majeure* is the existence of other buildings in close proximity to the building to be erected. It follows that, from the point of view of designing for daylight, buildings may be divided roughly into two classes, viz.: (a) isolated buildings, or buildings in areas so open that the effect of neighbouring structures may be neglected; (b) buildings in built-up or, worst of all, congested areas.

### Buildings on Open Sites.

The former class naturally presents by far the simplest problem and, in fact, a few general principles suffice to ensure that the daylight will be ample for so long as the condition of virtual isolation of the building can be guaranteed. In view of the conditions which may be expected to prevail in the post-war period, it is probable that the proviso at the end of the last sentence should be underlined.

For a room with an unobstructed outlook the two factors which govern the amount of daylight received at any point are (a) the total effective area of the window in relation to the size of the room, and (b) the height of the window-head above the working plane. Speaking broadly, it may be said that for all parts of the room except those near the window, a given area of glass becomes more and more effective as its height above the floor increases. This is well illustrated in Table I, which gives the daylight factor at a certain point in a room lighted by a window 4 ft. wide, with the window-head at various heights above the working plane.

TABLE I.

| Height of Window-head. | Daylight Factor. |
|---|---|
| 10 ft. | 1.38 per cent. |
| 9 | 1.10 |
| 8 | 0.83 |
| 7 | 0.57 |

The point for which the daylight factor has been calculated is on the working plane (assumed to be 6 in. below the window-sill) and 12 ft. from the vertical line through the centre of the window. It will be seen that for a window-head of 10 ft., for instance (i.e., approximately 7 ft. 3 in. above the working plane), the daylight factor is 25 per cent. greater than for a window-head of 9 ft., and it can easily be shown that an extra foot at the top is, in this case, worth four times as much as a foot at the bottom of the window. The conclusions to be drawn from this are, clearly, that windows should be carried up as nearly as possible to the ceiling and that ceiling heights should not be too low.

This matter of ceiling height is of the greatest importance in securing adequate daylight for buildings in built-up areas, even more than for those in open positions, and it will be referred to again in a later section of this paper.

### Built-up Areas.

The problem of securing adequate daylight in built-up areas is often very complicated, since the designer of the building under consideration has to take into account the obstruction to daylight caused by buildings in the immediate neighbourhood, either those actually in existence or those which may be erected under the building regulations applicable in the locality There are, therefore, two complementary problems to be solved when a programme of buildings is being planned. First, it is necessary to frame regulations so as to ensure that every building shall have its fair share of daylight and that no building shall be allowed to cause more than a certain permissible obstruction to any other building. Secondly, on the assumption that all buildings in the locality will conform with these regulations the architect must design each building so as to give the occupants of every room as much daylight as possible, having regard to all the many other amenities which it is equally his duty to provide.

Again, members of this Society will be familiar with the papers on this subject which have been published at various times, notably those presented at meetings of the International Commission on

* See, for example, P. J. Waldram and J. M. Waldram, Illum. Eng., Vol. 16, 1923, p. 90, and P. J. Waldram, J. Roy. Inst. Brit. Archit., Vol. 43, 1936, p. 1,072. "Penetration of Daylight and Sunlight into Buildings," Illum. Research Technical Paper No. 7 of Dept. of Scientific and Industrial Research (2nd edit.), H.M.S.O., 1932, with Appendix by P. J. Waldram. J. Swarbrick, Architects' J., Vol. 70, 1929, p. 618. H. H. Higbie and A. D. Moore, Int. Illn. Congress, 1931, Proc., Vol. 2, p. 1,149. See also the references to the protractor method on p. 7 *infra*. For a mathematical treatment of the subject see A. C. Stevenson, Int. Illn. Congress, 1931, Proc., Vol. 2, p. 1,167.

Illumination in 1928 and 1931, but a brief summary of the position will not be out of place.

### Building Regulations.

The need for regulations arises largely from the fact that in built-up areas the amount by which a building may be permitted to obstruct the light that would otherwise reach its neighbours has to be arrived at by a compromise between two opposing considerations. In towns, where land values are high, economic pressure has in the past usually called for a high concentration of lofty buildings, a state of affairs quite incompatible with good daylight conditions.

As an example of methods of approach to this problem, reference may be made to proposals regarding the heights of buildings made by the L.C.C. in 1936.* In these, three height zones are prescribed, according to the nature of the buildings predominant in each. Zone 1 includes central business areas and areas used for basic industry, Zone 2 covers areas in which multiple dwellings preponderate, while Zone 3 is residential in the ordinary sense. The proposals include, for each zone, two maximum heights, neither of which may be exceeded. One of these maximum heights is in terms of the distance away of the neighbouring buildings, while the other depends on the nature and purpose of the bulding to be erected. The actual values are as follows:—

| Zone. | Ratio of height to distance from opposite side of street. | Max. overall height. | | |
|---|---|---|---|---|
| | | Single-family dwelling houses. | Other residential buildings. | Commercial and Industrial buildings. |
| 1 | 1½ : 1 | 60 ft. | 80 ft. | 100 ft.* |
| 2 | 1¼ : 1 | 40 ,, | 60 ,, | 80 ,, |
| 3 | 1 : 1 | 40 ,, | 40 ,, | 60 ,, |

* There is an over-riding maximum of 80 ft. for the sheer height of any building.

Another method which has been proposed is to prescribe that no building should present a greater obstruction than a continuous building of unlimited breadth of a definite height at a definite distance.† This requirement by itself is not sufficient, since two buildings of different form may well cause the same amount of obstruction in one room of a neighbouring building but quite different amounts in another room differently situated. To make the requirement precise it would therefore be necessary to describe in some detail the area for which the obstruction is to be determined.

Once the maximum possible obstruction due to neighbouring buildings has been defined, either by one of the two methods just described or in any other way, the architect can calculate precisely for his proposed building how much daylight (at least) each room will enjoy. This he can do by one of the methods to which reference has been made earlier in this paper, but although, as there stated, it is now quite possible to calculate the daylight factor for any and every point in a room, whether the outlook be obstructed or not, it will be readily understood that the presence of external obstructions, especially if these are at all irregular in shape, complicates the calculations and increases considerably the amount of work involved. It is fortunate, therefore, that there is a comparatively easy method of calculating roughly, but usually quite well enough to form a preliminary estimate, what area in a room with an obstructed outlook has a daylight factor of less than 0.2 per cent. and is therefore inadequately daylighted.*

### The No-Sky Line

This method depends on the observed fact† that in side-lit rooms, obstructed by buildings which are approximately uniform in height and which extend across the whole lateral aspect of the windows with an angle of elevation of some 30° or more, the daylight factor on the working plane drops to 0.2 per cent. at positions which are quite close to those where it just ceases to be possible to see any portion of the sky between the head of the window and the top of the obstruction. A line joining such "no-sky" positions therefore indicates at once how much of the room receives inadequate daylight.

To show how closely the "no-sky" line lies to the contour of 0.2 per cent. daylight factor, Table II. has been calculated for a room lighted by a window 4 ft. wide with a window-head 6 ft. above the working plane, facing a row of uniform buildings on the opposite side of the street. The distances shown on any line in columns (2) and (3) are the distance from the window, measured along the centre-line of the room (assumed symmetrical), at which respectively the daylight factor is 0.2 per cent. and the "no-sky" point occurs when the angle of elevation‡ of the obstructing buildings has the value shown on the same line in column (1).

TABLE II.

| Angle of Elev. of Obstruction. | Distance to 0.2% d.f. | Distance to No-sky Point. |
|---|---|---|
| (1) | (2) | (3) |
| 25° | 11′ 5″ | 12′10″ |
| 30° | 9′ 7″ | 10′ 5″ |
| 40° | 7′ 0″ | 7′ 2″ |
| 50° | 4′11″ | 5′ 0″ |
| 60° | 3′ 5″ | 3′ 6″ |
| 70° | 2′ 2″ | 2′ 2″ |

It will be noticed that in every case the 0.2 per cent. daylight factor occurs slightly nearer the window than the no-sky point. This must be so since in the calculation no allowance has been made for any light reflected from the surface of the obstruction, so

* London County Council, Report of the Town Planning and Building Regulation Committee (No. 1), March, 1936.

† See P. J. Waldram, J. Roy. Inst. Brit. Archit., Vol. 42, 1935, p. 1,091, and Vol. 44, 1937, p. 1044.

* It is suggested that the subject of natural lighting has now reached the stage at which convenience and brevity demand the use of the verb "to daylight" and the verbal noun "daylighting."

† "Penetration of Daylight and Sunlight into Buildings," Illumination Research Technical Paper No. 7 (H.M.S.O., 1932), p. 14.

‡ Measured at the window-head.

that the calculated daylight factor at the no-sky point is necessarily zero. Owing to this reflected light the 0.2 per cent. daylight factor will occur rather further from the window than the calculation shows, but the difference will be very small. As an example, if the reflection factor of the obstruction be taken as 20 per cent. (and this is probably high for a town building) the brightness of the upper part of the surface will be one-tenth of that of the sky, and the daylight factor at the no-sky point with a 40° obstruction, when calculated, is found to be 0.18 per cent. Thus in general it may be assumed that the no-sky line is a good indication of the limit of adequacy of the daylight in a room except when the obstruction is small (and therefore no problem arises) or when, due to the irregular outline of the obstruction, a very small piece of sky remains visible for some distance behind the positions at which by far the greater part of the sky has disappeared.

### When Is a Room Adequately Lighted?

An attempt will be made to see how the principles described above may best be applied in practice to the design of large buildings in towns, particularly those two classes which will probably be of the greatest interest in post-war construction, viz., large blocks of multiple dwellings and large office buildings.

In 1931 the British National Illumination Committee put forward, quite tentatively, suggestions for standards of adequate lighting in terms of the percentage area of a room to be daylighted to a 0.2 per cent. daylight factor. These are given in Table III.

TABLE III.

"Minimum proportion of rooms over which daylight illumination at table height adequate for ordinary purposes is desirable."*

| Rooms used for:— | Per cent. |
|---|---|
| Domestic Purposes : | |
| Kitchens and Sculleries ... ... | 100 |
| Sitting Rooms ... ... ... | 50 |
| Bedrooms ... ... ... ... | 30 |
| Offices for Clerical Work ... ... | 40 |
| Drawing Offices ... ... ... | 50 |
| Manufacturing Processes ... ... | 40-80 |

Once a figure such as those quoted in the above table has been decided for any given class of room, it is a fairly simple matter to determine what must be the relation between the three governing quantities (i.) depth of room, (ii.) height of window-head, and (iii.) maximum angle of elevation of permissible obstruction.

For instance, if the figure of 50 per cent. be accepted for sitting rooms, it is clear that the line joining a point at table-height in the middle of the room to the mid-point of the top of the window must clear the top of the building obstructing the outlook from that room, assuming that this building is parallel to the window wall of the room. Alternatively, the plane defined by the top of the obstructing building and the middle point of the room at table-height must not be intersected by any part of the wall forming the window head. Fig. 1 illustrates what is meant, and it will be clear at once that, with a given obstruction, ceiling heights must be greater, or rooms must be made less deep on the lower floors of a building if the same standard of daylighting is aimed at throughout. Building regulations clearly cannot do more than, in effect, limit the angle of elevation of an obstruction as measured at a given point in the obstructed building. For instance, the limits laid down in the L.C.C. proposals (see above) are equivalent, as regards the figures shown in col. (2) of the table, to angles of elevation of 56½, 51½, and 45° respectively, measured at the *base* of the obstructed building. The angle at the window-head on the ground floor, which is the important matter from the point of view of daylight, will be slightly smaller by an amount depending on the distance between the buildings and the height of the window-head. Given

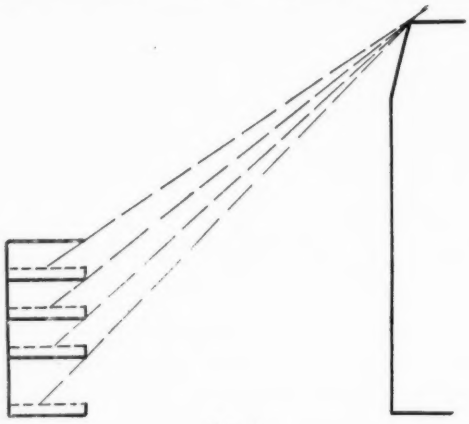


Fig. 1.

limits such as these, the architect can design his building so as to secure any specified amount of daylight, and in what follows some of the factors which may influence the design in any given case will be considered.

### Building on an Island Site.

The planning of a large block of buildings to occupy an island site to the best advantage from the point of view of daylight has received a good deal of consideration, and the merits of the external light well (i.e., a well completely open at one side) have been pointed out. In a paper read before the International Commission on Illumination in 1928* five different methods of developing a typical island site in a large town were described, and the areas receiving direct skylight were determined in each case. Briefly, the five plans were on the following lines: (i.) Two internal light wells, (ii.) one large internal well, (iii.) four external wells, (iv.) two internal and two

* Comm. Int. de l'Eclairage, Compte rendu des Séances, 1931, p. 216.

* J. G. West, "Daylight Illumination in Respect to a Typical Building Site in a Large Town," Comm. Int. de l'Eclairage, Compte Rendu des Séances, 1928, p. 492.

external wells, (v.) two large external wells (plan, similar to letter H.). Scheme (v.) provided the best daylight, but the smallest available room area. Scheme (ii.) provided the greatest room area, but the fraction skylighted was less (45 per cent. instead of 56 per cent.). The worst schemes were (i.) and (iv.), those in which the lighting was partly dependent on internal wells of comparatively small area, and the conclusion was drawn that internal courts should be of the greatest possible size.

In a paper presented to the International Illumination Congress in 1931* a description was given of alternative plans put forward for the headquarters of London Transport at St. James's Park. One plan provided for three internal light wells, while the other, which was adopted, was cruciform in shape, so that, in effect, the lighting was from four external wells, each open on two sides instead of one. The difference in the daylighting is remarkable and the plans showing the respective areas on the first floor which are skylighted in the two cases are well worthy of careful study.

The cruciform plan possesses the great advantage that not only is the lighting from very open external courts but, in addition, the walls of each wing, instead of being parallel to the buildings facing them on the opposite side of the street, are inclined at angles varying from about 30 to 60 degrees.

Although it may not always be practicable, the arrangement of buildings so that the walls are at about 45 degrees to the street and not parallel and at right angles to it, possesses such great advantages in securing good daylighting that it demands very careful consideration. Figs. 2a and 2b will serve to illustrate what is meant. They show an island site 200 ft. square, the distances between the building lines being 70 ft. on all four sides. The surrounding buildings are all 80 ft. in height, so that the angle of elevation of the obstruction to a ground-floor window in building A is 45 degrees, measured at the window-head, which is taken to be 10 ft. above ground level. For all the outward-facing ground-floor rooms in building A, then, the no-sky line is 10 ft.—2 ft. 9 in.= 7 ft. 3 in. back from the outside surface of the wall. In building B, however, matters are quite different. Here the no-sky line is at 45° to the walls, being the intersection of the working plane with a plane

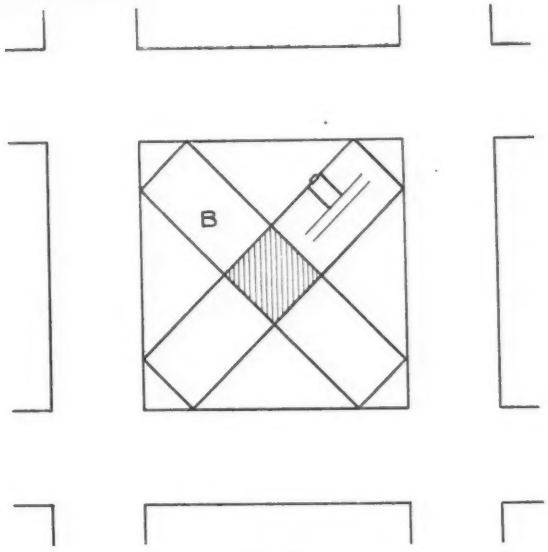



Fig. 2b.

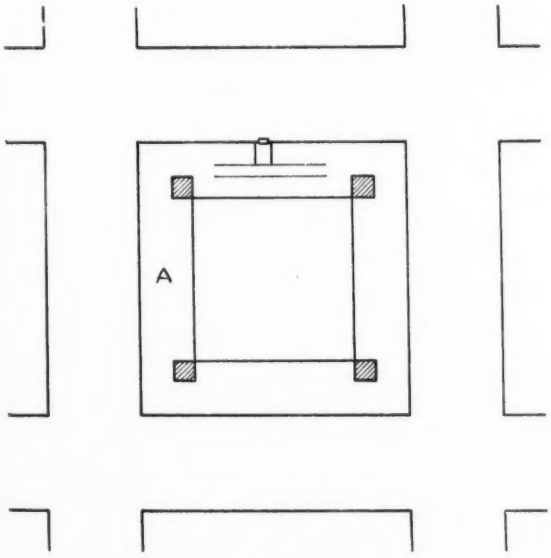



Fig. 2a.

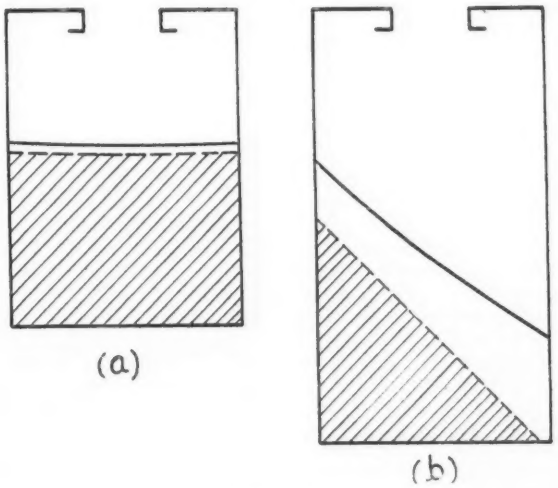



Fig. 3.

*P. J. Waldram, "The Provision of Adequate Daylight in Building Regulations," I.I.C., Proc., Vol. II., p. 1,117.

passing through the top of the obstruction and the corner of the window-head farthest from the obstruction. For a room in the centre of one of the wings it is shown on the enlarged plan in Fig. 3b, the corresponding plan for an outward-facing room in building A being shown in Fig. 3a. It will be seen that for the rooms in building A, taken as 16 ft. deep, approximately 55 per cent. of the working plane receives no direct light from the sky, while for the rooms in building B, taken as 22 ft. deep, this percentage is on the average less than 25. (The different depths of room have been taken so as to give approximately the same total room area for both buildings.)

There is one point which must not be lost sight of when considering the obstruction caused by a building running at 45 deg. instead of parallel to the window wall, viz., that it does not strictly fulfil the condition laid down for the use of the no-sky line as indicating the position of the 0.2 per cent. d.f. contour; the requirement that it should be "approximately uniform in height and extend across the whole lateral aspect of the window" is not fulfilled. The last bit of sky to disappear is, in fact, a tiny triangle at one of the top corners and not a horizontal strip extending right across the top of the window. It has been thought worth while, therefore, to determine the actual position of the 0.2 per cent. d.f. contour in the case of the two rooms shown in Fig. 3. All reflected light from the obstruction has been neglected, so that, in fact, the real contour lies rather nearer to the no-sky line than that shown in the figure. The jamb of the window has been taken as 1 ft.

It will be seen that, although the distance between the no-sky line and the 0.2 per cent. contour is considerably greater in the case of the room with the inclined obstruction, Room B, than it is for a room with a parallel obstruction, yet B is still found to have a very much smaller area inadequately lighted. If the area behind the 0.2 per cent. contour is measured in each case it will be found that the fraction of the room which is inadequately lighted is about 58 per cent. in the case of Room A, as compared with 43 per cent. for Room B.*

For rooms on the first floor the difference is perhaps even more striking. Fig. 4 shows the no-sky lines for rooms immediately over those to which Fig. 3 refers, the height of window-head being taken as 20 ft. above ground level in this case.

It would be interesting to explore the matter further and to draw plans corresponding to those in Figs. 3 and 4 for rooms of different dimensions and, more especially, for different window heights. Probably enough has been said, however, to show that this form of lay-out has a good deal to commend it from the point of view of securing adequate daylight in the lower floors of a building. In fact, the only alternative is to make a very considerable increase in the height of the rooms on the lower floors so as to allow the window-heads to be much higher. This is the proposal implicit in the "Standard of Reasonable Modern Fenestration" put forward by the Royal Institute of British Architects.* In this a nine-storey building, 80 ft. to the parapet at the top of the seventh storey, is shown as having all storeys 10 ft. between floors, except the lowest three storeys, where this dimension is given as 11 ft. 6 in., 13 ft. 6 in., and 14 ft. 6 in. respectively. Increasing the height of the windows on the lower floors is, in fact, the method commonly adopted for large blocks of offices in congested areas.

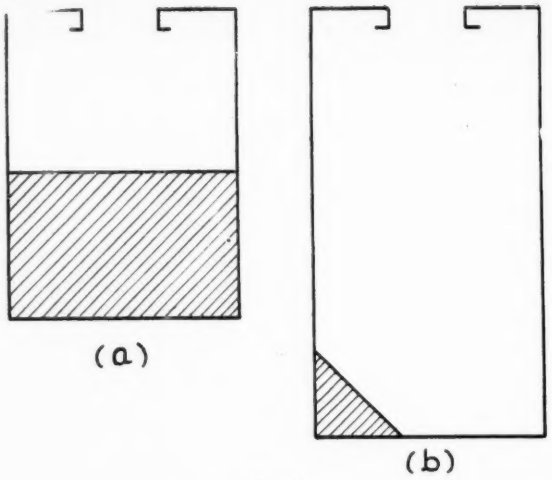



Fig. 4.

### Balconies

It will be clear that the principles described in the foregoing paragraphs are applicable equally to office buildings and to multiple dwellings. In the latter, however, there is a special feature, which arises from the necessity for direct access to each individual flat, and which in many cases affects the amount of daylight reaching certain rooms. It is not at all unusual to find that the balcony giving access to the flats on one storey projects some 4 ft. immediately above the window heads of the rooms in the storey beneath, and, unfortunately, as the balconies are usually at the back of the building, it is the kitchens which suffer in this way. The effect of even a narrow balcony in reducing the light entering a window is very marked† if the window faces an obstruction on the other side of the road, and the result may well be that practically no direct skylight enters the room at all; in other words, the whole of the room is always inadequately daylighted. That this is by no means an impossible condition is shown by Fig. 5, which should be compared with Fig. 1. It is probable that, in order to avoid the necessity for a balcony, some additional space will be required for staircases and short internal passages, but the value of a well daylighted kitchen can scarcely be overestimated, and, in fact, it will be noticed that in Table III. it is recom-

* In this calculation, as in the plans, the small areas of inadequate lighting in the corners of the room near the windows have been neglected.

* Journal, Vo'. 37, 1930. p. 382.

† H. E. Beckett, "The Obstruction of Light by Balconies," Architect and Building News, Vol. 143, 1935, p. 133.

mended that the minimum proportion of adequately lighted area should be 100 per cent. in the case of kitchens and sculleries, as compared with only 50 per cent. for sitting rooms.

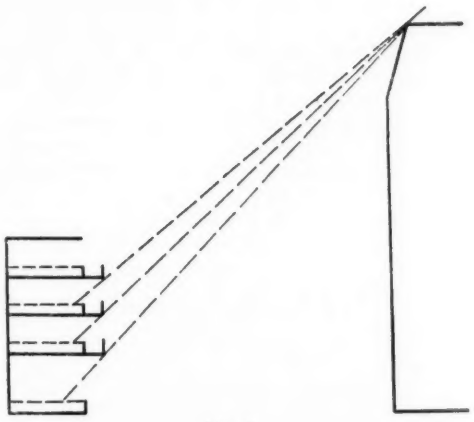


Fig. 5.

## Schools, Factories, and Other Buildings

The daylighting of buildings other than office blocks or multiple dwellings is, of course, subject to the same general principles as those already mentioned, but in many cases the special purpose for which the building is intended will call for a higher standard of daylight. For instance, in the Board of Education's "Suggestions for the Planning of Buildings for Public Elementary Schools" it is laid down (§100) that "No position in a classroom is fit for use as a school place unless the sky is visible from it at desk or table height. The area of sky visible should be sufficient, at least, to offer an illumination on a horizontal plane at desk or table height equivalent to a daylight factor of point five per cent. . . . This value, however, should be regarded as a minimum which might be materially exceeded in new schools, where a daylight factor of 1 per cent. should be aimed at."

With regard to factories, there is at present little information regarding the minimum daylight illumination necessary for carrying out various types of work. Although a start has been made in supplying such data* much more research is needed along the same lines in order to provide the necessary guidance to designers of factory buildings. Meanwhile, it is important to remember that it has now become common practice to provide the values of artificial illumination recommended in this Society's "Code." Thus, 10 ft.c. is now quite a moderate figure, and, of course, 6 ft.c. is the minimum demanded in certain classes of factories. Given the average value of external daylight throughout the day at different times of year, it is clearly possible to calculate for how long, on the average, a point at which the daylight factor has any given value will enjoy an illumination of at least 10 ft.c. Examples (adapted from the publication referred to above) are given in the following table:—

TABLE IV.

Period during which the Daylight Illumination exceeds 10 ft.-candles.

| Daylight Factor. | | Jan. | Feb. | Mar. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|
| 4% | a.m. | 8.45 | 8.0 | 6.45 | 7.0 | 8.15 | 9.0 |
| | p.m. | 3.30 | 4.30 | 5.30 | 4.30 | 3.15 | 2.45 |
| 2% | a.m. | 9.45 | 8.45 | 7.15 | 7.45 | 9.15 | 10.30 |
| | p.m. | 2.45 | 3.45 | 5.0 | 4.0 | 2.15 | 1.30 |
| 1% | a.m. | None | 11.30 | 8.45 | 8.45 | None | None |
| | p.m. | — | 1.45 | 3.30 | 3.0 | — | — |

It will be seen from this table that, for a factory in which the daylight factor is anything less than 5 per cent., artificial light will be required for a considerable fraction of the working day during the winter months. Thus, in order to provide good daylighting in a side-lighted factory the windows must be very much larger and much higher than is necessary for an office or dwelling. In a roof-lighted factory it is naturally much easier to provide considerably higher values of daylight factor, and in this connection attention is drawn to a note on "Daylighting for New War Factories," which forms an appendix to War-time Building Bulletin No. 1 of the Department of Scientific and Industrial Research. This note makes certain recommendations as to the design of roof lights and describes an approximate method for estimating rapidly the daylight factor from a series of roof lights of considerable length, with their upper and lower edges horizontal and parallel. (The case where the window is sloping, not vertical, is treated in Bulletins Nos. 4 and 15a.*) This method has been improved since its introduction and a complete set of daylight factor protractors now enables a draughtsman to compute rapidly from a drawing a reasonably accurate daylight factor for any condition of glazing.

## Insolation.

The access of sunlight (as distinct from daylight) to the rooms in a building is a matter of considerable importance from the point of view of comfort and hygiene, and the report of the Health Organisation of the League of Nations, to which reference was made at the beginning of this paper, contains an excellent treatment of this subject. In this document it is pointed out that "architects and town-planning specialists have a variety of methods at their disposal for determining the insolation of façades, the interior of dwellings and streets, both existing and projected. By these methods, for example, the duration of possible insolation or the volume of solar radiation received by a wall surface or a dwelling with a given obstruction or fenestration can be determined for the various latitudes and solar elevations. They also make it possible to determine

* L. H. McDermott, "Daylight Illumination Necessary for Clerical Work," Illumination Research Technical Paper, No. 19 (H.M.S.O., 1937).

* See also A. F. Dufton, J. Sci. Insts., Vol. 17, 1940, p. 226.

the orientation, fenestration, and spacing (height of buildings, width of streets and courts) necessary to ensure the desired insolation of a building or dwelling as well as of the various individual rooms." These methods have been described in various published papers.* The problem of seeing that every dwelling in a town has its share of direct sunlight is, nevertheless, not always an easy one. Where any considerable area is being planned afresh, however, this object should always be kept in view and, in fact, "a town-planning expert cannot be satisfied with merely ensuring proper illumination for all rooms: he has to set himself a higher aim in ensuring direct sunlight for all dwelling houses. . . ." The writer of the foregoing paragraph† then continues: "This is easily done in giving all the secondary streets an approximately north-south direction, so that all dwelling rooms should face east or west, the main arteries keeping their direction determined by traffic conditions and other considerations."

The subject is admittedly a difficult one, at any rate in built-up areas, but it seems to be generally agreed that sunlight is of the utmost importance to the health of the community, quite apart from its great amenity value, and it therefore seems to be essential that the architect and town-planning expert should take this matter also into careful consideration in any programme of post-war building.

### Recommendations.

The broad conclusions to be drawn from what has been stated above may, perhaps, be summarised as follows:—

(a) Standards of adequacy of daylighting should be agreed for different types of rooms according to the purposes for which they are to be used. (With regard to factories see (f) below.)

(b) Building regulations should ensure that it is possible for the architect, by proper design, to secure these standards of adequacy in all rooms which might reasonably be required for living or working during the day.

(c) Window-heads should be as high as possible and, in order to assist in this direction, building by-laws should require certain minimum ceiling heights which might vary with the nature of the building and of the locality in which it is to be erected. It is suggested by the author that 8 ft. 6 in. should be the very minimum (except, perhaps, at the top of a building) for any room which is to be used for living or for working during any considerable period in the daytime.

(d) External light wells are, in general, preferable to internal courts, but where the latter are used they should be of the largest possible size. Building by-laws should prescribe certain minima for the area, and the dimensions of an internal court in relation to the height of the building. The cruciform plan and the arrangement of blocks of buildings diagonally to the building line, instead of along or parallel to it, frequently offer great advantages from the point of view of daylight.

(e) The placing of a balcony, or any other obstruction so as to project just over a window-head, should be avoided unless the outlook from the window under the balcony is otherwise almost completely unobstructed.

(f) More information is required as to the daylight necessary for factory processes. Meanwhile a daylight factor of 5 per cent. is suggested as the minimum for the working area in a factory, except where the work being carried on is of the roughest.

(g) Wherever practicable, every dwelling should be so designed that the rooms on one side at least can enjoy direct sunshine for a minimum of one hour per day at mid-winter.

It must be emphasised that the above recommendations are put forward mainly as a basis for discussion, considering that one of the principal objects of the papers read before the Society this session is to provoke members to state their views. The author has stated his in the hope that the discussion to follow will show what measure of general agreement can be arrived at on these and similar matters concerned with the daylighting of post-war buildings.

## APPENDIX

### Note on the Construction of "No-Sky" Lines for Regular Obstructions.

When the obstruction to a window is a building of uniform height parallel to the window opening, the principal element of the no-sky line is clearly the intersection of the working plane by a plane passing through the top of the obstruction and through the outside of the window-head. If h is the height of the window-head and H that of the obstruction, both measured from the working plane, the no-sky line is a line parallel to the window wall and at a distance a from the outside, where $a/h = w/(H-h)$, w being the distance of the obstruction from the window. Each side portion of the no-sky line is obtained by

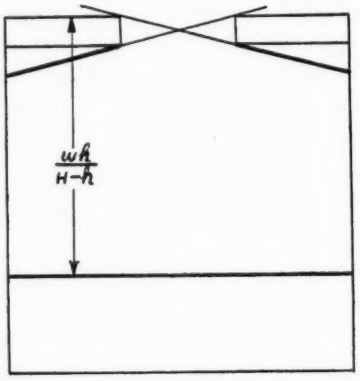



Fig. A1.

* See, for example, P. J. Waldram, "Planning for Sunlight," J. Surveyors' Instn., Vol. 2, 1923, p. 432. (See also Illum. Eng., Vol. 16, 1923, p. 109.) "The Penetration of Daylight and Sunlight into Buildings," Illumination Research Technical Paper, No. 7 (H.M.S.O., 1932), Appendix I. A. F. Dufton and H. E. Beckett, "The Heliodon," J. Sci. Insts., Vol. 9, 1932, p. 215.

† Ch. G. Möller, "Daylight Illumination and Town Planning," Int. Illumination Congress, 1931, Proc., Vol. II., p. 1,143.

drawing a line on the working plane to pass through the outside of the jamb on one side of the window and the inside of the jamb on the other side. (See Fig. A1.)

When the obstruction is not parallel to the window wall, although the greater part of the no-sky line is still a straight line, one of the side portions is part of an hyperbola. Let the conditions be as indicated in plan in Fig. A2. The obstruction, of uniform height H, makes an angle $\theta$ with the window wall and the line at which this obstruction would intersect the outside of the window wall, if both were produced, is at a distance d from the further jamb. The point at which the outer edge of this jamb intersects the working plane is taken as the origin of co-ordinates.

If P is a point on the no-sky line, its co-ordinates x (positive to the right) and y (positive downwards) can be calculated quite simply.

For the portion of no-sky line to the left of the broken line the jamb has no effect, and from simple geometry

$$h/PA = (H-h)/AB$$

Since $AB/\sin\theta = d/\sin(A-\theta)$ and

$\sin A = y/PA$, $\cos A = -x/PA$ this gives as the equation for the line

$$x+y\cot\theta = dh/(H-h)$$

which, of course, is a line parallel to the obstruction.

For the portion of no-sky line on the right of the broken line it will be seen from Fig. A3 that now

$$AB/\sin\theta = (d-a)/\sin(A-\theta)$$

and $\cos A = -(x+a)/PA$ where a is the distance of A from the jamb. If the width of the jamb is t, $a/t = x/(y-t)$ and the equation of this part of the no-sky line is found to be

$$y(y\cot\theta+x) - yt\cot\theta = \{d(y-t) - tx\}\, h/(H-h)$$

This is a hyperbola of which the asymptotes are

(i.) $y = -ht/(H-h)$, i.e., a line parallel to the window wall at a distance $ht/(H-h)$ from it on the outside, and

(ii.) $x + y\cot\theta = (hd + Ht\cot\theta)/(H-h)$, i.e. a line parallel to the straight line portion of the no-sky line and further from the window. It is to be noted that the curve passes through the point $x=0$, $y=t$, i.e., the inner edge of the jamb on its own side.

The most interesting practical cases are, probably, $\theta=90°$ ($\cot\theta=0$) and $\theta=45°$ ($\cot\theta=1$). In the former case the equation to the hyperbola (now rectangular) becomes

$$xy = \{d(y-t) - tx\}\, h/(H-h)$$

the asymptotes being $y = -ht/(H-h)$ and $x = hd/(H-h)$. In the latter case the equation to the hyperbola is

$$y(x + y - t) = \{d(y-t) - tx\}\, h/(H-h)$$

with asymptotes

$$y = -ht/(H-h) \text{ and } y+x = (hd+Ht)/(H-h)$$

Remembering that a vertical edge at the end of an obstruction may be treated in the same way as the vertical edge of a window jamb, it will be seen that it is a simple matter to draw the no-sky line for any obstruction of which the outline is composed of horizontal and vertical lines. A simple case has been worked out and is shown in Fig. A4. The dimensions taken are as follows:— $\theta=45°$, $H=77'$, $h=7'$, $t=1'$, $d=140'$. This is almost identical with the case illustrated in Fig. 3b of the paper.

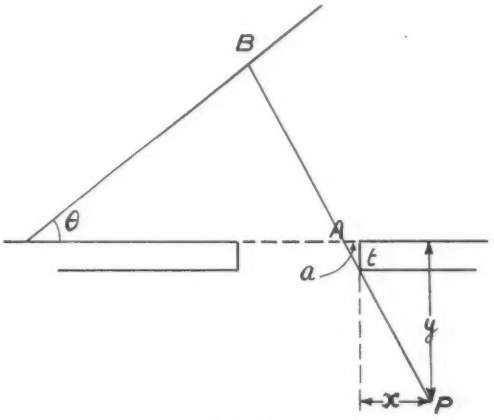



Fig. A3.

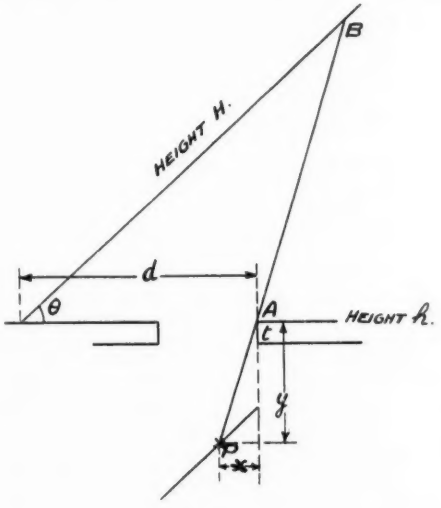



Fig. A2.

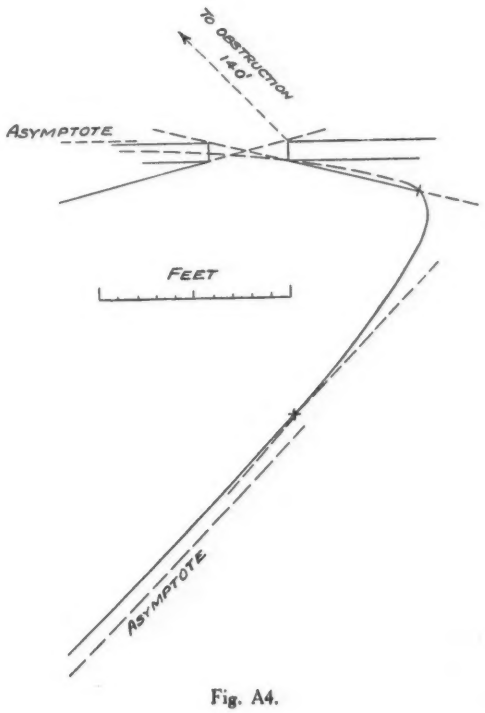



Fig. A4.

# DISCUSSION

Mr. P. J. WALDRAM, in opening the discussion, said it was essential that criticism of this paper should be thorough and careful. In formulating even tentative standards when planning for daylight one was virtually instructing architects and town planners—practical men who knew well the physical limitations of their job—in regard to fenestration and building restriction. Planning for daylight, however, thrust on these experts tasks with which they had had little opportunity to become familiar. It was only after permissible degrees of obstruction had been standardised, under the 1932 Act, that the town planner had legal authority to restrict new buildings and the architect was able to visualise the ultimate surroundings of and obstructions to his building.

In the times of Queen Anne and the early Georges the architect could be fairly certain in towns of nothing worse than houses 40 to 50 ft. high on the opposite sides of streets 50 ft. wide. He could then design buildings which were delightfully lit. But when buildings grew higher and higher architects gave up scientific fenestration in despair. Only now could they await from town planners a reasonable opportunity of recovering a lost art.

The paper conveyed the impression that if architects mastered the mathematics of no-sky lines they could readily practice scientific fenestration in buildings on open sites, or in towns if given proper building restrictions. Unfortunately, there was much more in fenestration than that. Building restriction, also, was no small matter. It must be graduated to the varying needs of different classes of neighbourhood. It must hold the balance fairly between the claims of public health and amenity and the need for providing adequate space and opportunity for the development of industrial and commercial activities. Economic pressure due to high values in towns ought not, however, to affect any decision.

In the survey of past work given in the paper he noted certain omissions, such as the absence of reference to reports of committees on which various Government departments, including the D.S.I.R. were represented. Again, the I.C.I. proceedings were known only to a few. He hoped that Dr. Walsh would make it clear that he did not attempt to give a survey of all that had been done since the Society last considered daylight, nearly twenty years ago. Much fundamental work had been done by members of the Society (Trotter, Kerr, Nash, Dow, Clinton, Mackinney, and others) and recorded in "Transactions" long since out of print. His (Mr. Waldram's) own connection with the subject went back to many years ago. The "grumble point" of 0.2 per cent. daylight factor (1909)* was the result of a long series of measurements with the cardboard and glue attachment,† which first enabled the Trotter photometer to cope with daylight intensities and to prove the truth of the "ratio" system of measurement. Measurements made at University College with the late Professor Clinton establishing the truth of the theoretical conception of measurements on models were reported in February, 1914.‡

This long retrospect led to the conclusion that apparently satisfactory solutions of daylight problems should be very carefully scrutinised before acceptance. Even standards backed by good authority should be carefully examined. It was fatally easy to draw deductions from photometric data, forgetting the indifference of the eye to high photometric differences. He regarded as Utopian some of the suggestions in the paper, such as the proposed minimum daylight factor of 1 per cent. in schools and 5 per cent. for side-lit workshops, and the suggestion that dwelling houses should have living-rooms on one side enjoying a minimum of one hour of possible sunshine in mid-winter. He would like to know whether Table III. had even been tested. It had not been put forward by the I.C.I. Daylight Committee as an approved standard nor included in subsequent I.C.I. reports.

Dr. Walsh had criticised his suggestion of defining standard obstruction by height and distance, as an inadequate alternative to the L.C.C. proposed definition by height and angle. Yet it was precisely the same in effect, whereas the old criterion of angle only, which disregarded distance, was fallacious, as demonstrated in Technical Paper No. 7.

* "Illuminating Engineer," Vol. II., July, 1909, p. 469.
† "Illuminating Engineer," Vol. I., October, 1908, p. 811.
‡ "Illuminating Engineer," Vol. VII., Feb., 1914, p. 78.

It would be interesting to know the conditions under which Dr. Walsh had obtained the calculated value of 0.18 daylight factor (see p. 22). The figure was not general for obstructions subtending 40°, even to the dimensions stated, but varied with the distance of the obstruction and the height of the building obstructed.

Technical Paper No. 19 should not be regarded as settling the question of adequate lighting for clerical work. The paper drew inferences from the times at which a group of typists switched on artificial light—but it did not record whether they were transcripting from print or from typescript presenting good contrast, or from faint pencil shorthand requiring special light. It would be recalled that in a letter to the technical Press Mr. T. Smith (superintendent of the Lighting Department at the N.P.L.) had stated that this work did not supersede earlier reports and that more work, preferably on a larger scale, was needed before practical conclusions could be drawn. He (Mr. Waldram) knew of no reliable evidence of any widespread grumbling at anything other than 0.2 per cent. daylight factor for *ordinary* work, comparable with clerical work over reasonably long periods. The ingenious daylight factor protractor was devised in the course of answering an inquiry addressed to the Illuminating Enginering Society by the Departmental Committee on Lighting in Factories and Workshops.* In regard to insolation, reference should be made to the R.I.B.A. Report of a Joint Committee on the Orientation of Buildings, a valuable document which was stated to have had a considerable vogue on the Continent. In regard to the Appendix, no-sky lines had been used for years without anything more than simple graphic methods being adopted, and abstruse matnematics were unnecessary.

In conclusion, Mr. P. J. Waldram referred to the Town and Country Planning Act of 1932, and explained why it had proved ineffective in practice. When the Act came into force local authorities were given time to prepare properly graduated schemes of building restriction by being authorised to administer upon Interim Developoment Orders, treating each case upon which what they believed to be its merits. These decisions were nominally subject to appeal, but in practice were final. As should have been foreseen, authorities have been loath to exchange such pleasantly autocratic powers for definite ordered schemes under which every case would have to be treated alike. No effective time limit having been included, it was not surprising to find that in 1939 there was only *one* ordered scheme, that of the L.C.C., and that only in draft. Elsewhere there was only a mass of confused precedents on which decisions could be based. The L.C.C. scheme was, however, so simple in structure that it could be readily applied to any area.

The remedy was obvious. There should be a short Amending Act, sponsored by the Ministry of Health, fixing a reasonably short time limit within which each local town planning authority must deposit a draft scheme of building restriction or have one imposed upon it by the Ministry. The time for considering schemes was not when the war was over, or nearly over, and countless other new problems became urgent, but *now*.

Mr. A. F. DUFTON (Building Research Station) said that Dr. Walsh had performed a valued service by exposing his views upon the subject of planning for daylight. He would like to make a small contribution to the discussion.

In the first place, might he note an omission?—Dr. Walsh did not make any mention of the fact that, in general, a window is provided not only for the admission of light and sunshine, but also for the admission of air, and to enable a sight to be obtained of the outdoor world. As regards the admission of air, it was well said by Douglas Galton that although the windows, when they can be kept open, are the best means for the renewal of the air in a room, every room should nevertheless have special inlets and outlets for air, arranged to be independent of the windows. The admission of light, moreover, need not be subordinated to provision for seeing out of a room.

The next point which he wished to touch upon was the desirability of securing, as far as may be, uniformity of illumination in a room. As Rumford pointed out, the

*" The Builder," August 2, 1940.

momentary derangement of the eye in passing suddenly from a strong light to one much more feeble, and *vice versa*, renders it impossible to see objects so distinctly as they might be perceived *even with much less light* were the illumination established on better principles. The question of uniformity is likely to be important when standards of adequacy are discussed.

Coming to his third point, Mr. Dufton referred to Dr. Walsh's statement that for all parts of the room except those near the window, a given area of glass becomes more and more effective as its height above the floor increases. Dr. Walsh was speaking, of course, of the illumination upon a horizontal plane, measured in terms of the daylight factor. But, even so, the statement should not be allowed to pass unchallenged. The contribution to the daylight factor made by an element of vertical window increased with the altitude only up to a certain elevation above the working plane; it reached a maximum value and then decreased. For an unobstructed, unglazed window in a thin wall, he computed that the maximum occurs when the angle of elevation was 30°. For a glazed window the maximum was at a somewhat lower elevation.

Dr. Walsh's recommendation that window-heads should be as high as possible was likely to provoke criticism. In domestic premises it was desirable that windows should be contrived so that both the inside and the outside surfaces can be safely and readily cleaned even by a woman of less than average height. This was one argument in favour of keeping window-heads low.

In recent years there had been a vogue for rooms with very extensive windows. This was not a novelty, and he (Mr. Dufton) thought that we shall be well advised to remember the caution uttered by Francis Bacon: "You shall have sometimes fair houses so full of glass that one cannot tell where to become to be out of the sun or cold."

Mr. J. MARKHAM (Ministry of Works and Buildings) pointed out that nothing was said in the paper about aspect. Did that make no difference? Did it not matter whether a room was facing north, south, east, or west? The no-sky line depended on the height of the window, but nothing had been said about the width of the window surface, though that must surely affect the amount of light in the room, otherwise there would be no difference between a narrow slit which went up to the ceiling and a window which was the full width of the wall surface. The conditions of light intensity outside varied tremendously not only with seasons but almost from day to day in this country; and he wondered whether it would not be advisable to have as much glass as possible, and if the amount of glass provided admitted at times too much light, then some of the light could be shut out. The effect of temperature had also to be considered, so that when designing a room there must be a compromise between lighting and temperature requirements. Possibly other conditions, such as sound transmission, would also exercise an influence on window design.

Mr. EDWIN WILLIAMS (L.C.C. Architect's Department) referred to the mention of the Building Act and Town Planning Act restrictions, the purpose of which was to safeguard the public against undesirable extremes. Within such safeguards, it would appear wise to allow the public, through their experts and advisers, to have the maximum flexibility of choice as to the amount of daylight they desired according to the conditions in each case, each case being different as to the use and the environment of the premises concerned. It would not be desirable for the local authority to attempt to impose standards other than those necessary in the public interest. Such extremes were, for example, too little light for domestic purposes and, on the other hand, the over-stressing of the apertures to admit maximum daylight in load-bearing walls. A further safeguard of a rather different character related to the aesthetic point of view. This restriction need seldom come into operation where the public was advised by qualified architects. It was necessary, however, that we should know as much as possible about daylight from the scientific point of view, and it would be true to say that the London County Council would wish to keep an open mind on the subject.

Mr. H. E. BECKETT (Ministry of Home Security) said that a paper of this nature was badly needed at the present time. Under war conditions daylight was fighting a losing battle, since various factors such as obscuration, camouflage, and anti-splinter precautions all conspired to diminish the amount of daylight available in buildings. Therefore we needed to be reminded that the day would come when we could once more plan buildings to take full advantage of daylight.

He noticed that the author had been careful to avoid the temptation to claim too much for the daylight factor unit, which had been introduced as a means of overcoming the difficulties caused by varying sky brightnesses. It was later thought that the daylight factor might be a better unit than absolute intensity for measuring ability to see, and that view had been supported by the work which had led to the establishment of the "grumble point." It must be remembered, however, that the "grumble point" experiments related only to side-lit rooms and to conditions of inadequacy, and that there was still no indication that the "seeing" at a point in a building was determined mainly by the daylight factor at that point. Caution was particularly needed in dealing with top-lit buildings in which the daylight conditions were quite different from those in buildings lit by vertical windows.

He thought that Dr. Walsh should have distinguished between the photometric daylight factor determined by measurement, and the geometric daylight factor determined by graphical methods. Otherwise it was not always realised that, in computing geometric daylight factors, no allowance was ordinarily made for reflected light or for the effect of the window glass. At the Illumination Congress in Holland in 1939, a resolution defining the geometric daylight factor was very carefully framed; he believed the term "sky factor" was used to avoid confusion with the photometric daylight factor.

The reference in the paper to the L.C.C. height-zoning proposals gave the impression that high buildings were necessarily bad for daylighting. If that belief existed, he would like to dispel it at once, because it was quite easy to show mathematically that in housing a given population on a given site there was considerable advantage, from the lighting point of view, in using higher buildings more widely spaced.

He thought that the "no-sky line" had outlived its usefulness. When the science of daylighting was less highly developed it was difficult to measure daylight factors, particularly at the design stage, and the "no-sky line" had served a useful purpose. Now, however, simple methods of determining daylight factors had been developed and the "no-sky line" was no longer necessary.

He agreed generally with the author that balconies interfered seriously with daylight, but there were places where they could be useful. In a bedroom, for example, the loss of light due to a balcony might not matter much, while the balcony might serve the useful purpose of excluding hot summer sunshine, without interfering unduly with the desirable low-angle winter sunshine.

The author had quoted a rather sweeping statement that, for optimum insolation, streets should run north and south. That might be true of streets which were completely built up, but for the suburban streets with detached houses the best directions would probably be north-east to south-west and north-west to south-east. Whatever the street direction, a great deal more could be done by the architect than was usually done in arranging a building on a site so as to obtain the maximum benefit from sunshine. The author of the paper had said that methods for studying the insolation of buildings existed. It remained for the architects to use them.

Mr. A. S. E. ACKERMANN said that carrying windows up to the ceilings for reasons of illumination had the additional advantage of improving the ventilation.

Dr. Walsh pointed out the large amount of additional work

caused by an obstruction of irregular outline. One way to deal with this was to draw an averaging line through the silhouette of the tops of the obstructions, but in the case of an existing obstruction it was far more satisfactory to use his (Ackermann's) Skymeter. The ground-floor windows of Caxton House, Westminster, had circular arcs as their heads, with the additional complication of large ornamental keystones, and many large and irregular chimney stacks as the obstruction. In Mr. Ackermann's opinion it would have been impossible to get a reasonably correct result in this case without the use of his Skymeter, whereas, with it, the work was only a little more than if the window heads had been horizontal lines and the obstruction the same.

The procedure with the Skymeter was to trace the outline of the sky, on a sheet of glass, visible when looking through a small hole 13 in. from the glass, and 2 ft. 9 in. above the floor, the line of sight being from that hole to the centre of gravity of the outline of the sky and at right-angles to the plane of the glass. The area in square inches of the outline so traced, multiplied by the size of the angle of elevation of the line of sight, and divided by 5.62 gave the daylight-factor for the point represented by the eye-hole.

Dr. Walsh had suggested two useful words, viz., "to daylight" and "daylighting." Mr. Ackermann made the further suggestion that the "skyless line" was an improvement on the "no-sky line."

While on the subject of nomenclature, he would again remark on the fact that to engineers and land surveyors the term "contour line" meant a line joining points of equal height above the datum line. This, in fact, is the only meaning given in a dictionary. He preferred (in the case of illumination) the terms "isophotal line," i.e., a line joining the points in a room having the same intensity of illumination. This would take its place among the words isothermal, isobaric, isoclinal, isochronous, isogonic, and many others.

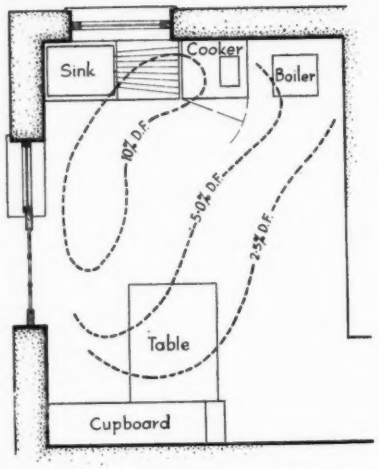
It was pointed out in the paper that the angle of elevation should be measured at the head of the window. In the old days of the angle of 45 deg. this was measured from the sills of the ground-floor windows. This angle, in the case of a room of average size and fenestration, gave about 50 per cent. of the room at table height as sufficiently lighted, and when a room was so lighted the Court appeared to be satisfied.

With regard to insolation, Mr. Ackermann said he was a keen sun-bather and certainly liked sunny rooms, but ordinary glass stopped ultra-violet radiation, which was the health-giving part of sunlight.

With regard to the appendix, in solving any problem he was prepared to use any method, or several methods, and adopted those which were the more simple; hence in this case he preferred the geometrical method of determining the skyless line, for it was so very simple. It was a pity that in the appendix "A" was used both for a point and also as an angle, when letters are cheap and numerous!

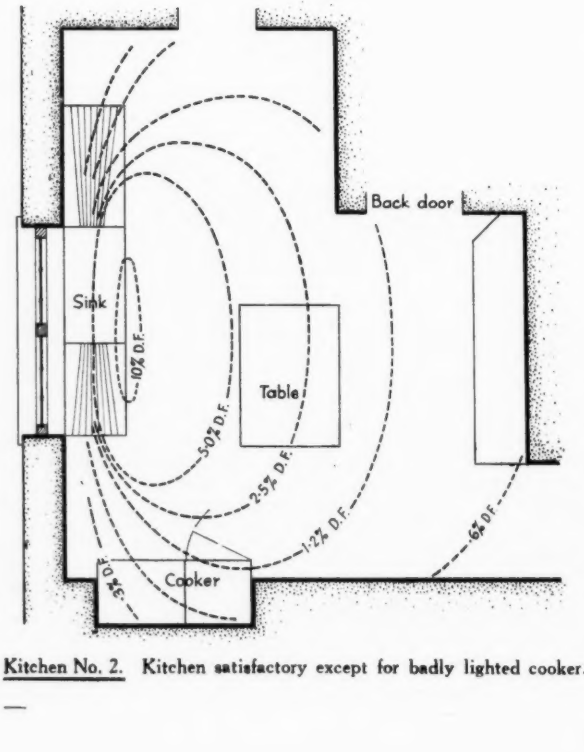
Mr. W. ALLEN (Building Research Station) expressed the view that agreement on standards for natural lighting systems was one of the most urgent lighting problems for the immediate post-war period, but he had never, personally, been convinced that the standards proposed in 1931 by the N.I.C., of which this paper reminded illuminating engineers, were adequate, or that they guaranteed the standard of performance which was intended. A drawing office could not, for instance, be considered satisfactory when half of it was inadequately lighted, or when the standard of adequacy was taken as 0.2 per cent. daylight factor, and the same applied to factories. The proposed standard for kitchens was more generous, but analyses of kitchens made at the Building Research Station showed that again it neither guaranteed the quantity of light needed nor the proper placing of the light.

Mr. Allen showed slides of three kitchens, remarking that No. 1 was considered generally satisfactory, except that light failed to penetrate the oven. The sink and work-table were

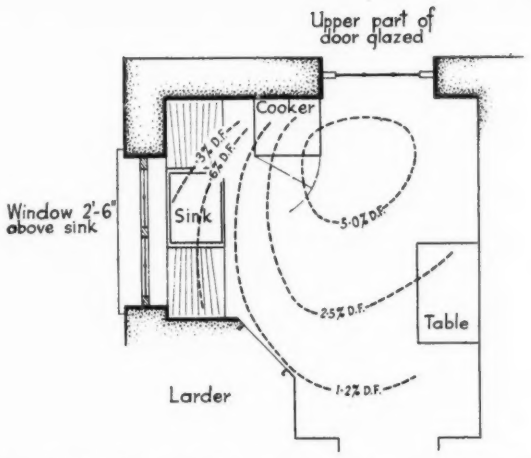



Kitchen No. 1. Kitchen satisfactory except for badly lighted oven.

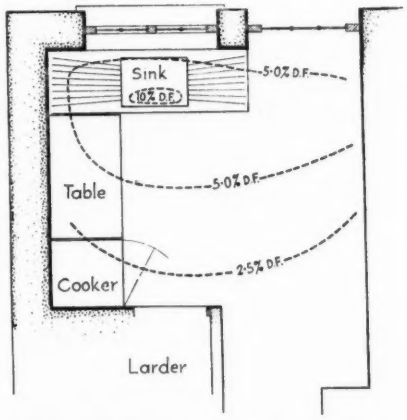
EXAMPLES OF KITCHENS, SHOWING THE EFFECT OF DISTRIBUTION OF DAYLIGHT AND THE DIMINUTION IN THE DAYLIGHT FACTOR AT POINTS MOST REMOTE FROM THE WINDOWS (MR. W. ALLEN).




Kitchen No. 2. Kitchen satisfactory except for badly lighted cooker.




Kitchen No. 3. Sink very badly lit; one works in one's own shadow; cooker and oven unsatisfactory; plan generally not very good for a corridor kitchen.




Kitchen No. 3 (Remodelled). Light where it is needed for washing, food preparation, and cooking; plan generally improved in other respects.

found acceptable, as they were in design No. 2, where the light was similar. The latter kitchen was, however, so dark at the cooker that artificial light has to be employed. Kitchen No. 3 was the worst, sink and oven being very unsatisfactory, largely due to the window over the sink being small and high; the work-table is little better, because one worked largely in one's own light.

The problem is primarily one of planning, on which the proposed standard exercised no influence, and to illustrate the ease with which a proper kitchen design could be prepared, Mr. Allen had redesigned Kitchen No. 3 as shown in No. 4. Here the light is well directed even for the oven, and of adequate intensity where it is needed. This plan was as well or better suited to the existing house as the original. Mr. Allen said that each of these kitchens conformed to the proposed N.I.C. standard, but obviously varied enormously in their suitability. In Mr. Allen's opinion such a room as a kitchen had to be considered a matter of local lighting. He hoped that when the problem was next considered much more specific standards would be found possible.

The suitability of recommendations or standards turned, of course, on whether they could be secured in practice. The daylight factor protractors introduced by Mr. Dufton to meet an early war-time problem of factory design had been invaluable at the Building Research Station, and it had been possible to ensure that the light distribution in B.R.S. standard war-time factories was adequate and also to ensure that the light was in the right place. In other words, the protractors had made it possible to conform in the factories to a high and specific standard, and Mr. Allen expected a wide extension of their use.

Mr. J. S. Dow remarked that whilst Dr. Walsh had devoted much consideration to the admission of daylight into buildings he did not seem to have said much about the choice of internal decoration in order to reflect and diffuse the light when it had entered the room. It was a familiar fact that the available illumination diminished enormously as one withdrew from the window. Diffusion of light from walls and ceilings had a valuable effect in alleviating these variations, and had also a material "shadow-value" in relieving the effect of unilateral lighting. The substitution, on walls and ceilings, of light coloured materials for dark ones would, he imagined, influence the daylight factor appreciably. Apart from this it had a definite psychological value in providing a light surround. He suggested, therefore, that some recommendation to the effect that light colours should be preferred for walls and ceilings ought to figure in the conclusions at the end of the paper.

Continuing, Mr. Dow inquired whether Dr. Walsh considered that the entry of sunlight into rooms was desirable during working hours. He was aware of the proverb to the effect that "where the sun does not enter the doctor comes," which presumably related to the germicidal value of ultra-violet rays, but admittedly the proportion of such radiation entering through ordinary window glass was not very great. On the other hand, it had always seemed to him that the extreme contrasts in brightness associated with the entry of direct sunlight were opposed to the principles of good illumination. It was not very often that direct sunlight penetrated into his own office, but when it attempted to do so he invariably pulled the blind down!

Dr. T. C. Angus (*Communicated*):—

I have proved to my own satisfaction that for myself a daylight factor of 1.1 per cent. is insufficient for the comfortable performance of carpentry, and that 4.8 per cent. is insufficient for filing, drilling, and metal work generally, as in a fitting shop, whereas daylight factors of 5.0 per cent. and 9.3 per cent. afforded sufficient illumination for continuous work without having to move or turn the work in order to examine it and without fatigue.

There is all the difference between ability to see sufficiently to perform some short task—such as putting in a fuse wire, and working continuously as does an operative assembling a radio set. It is this essential difference, between thresholds of seeing and the daylight illuminations desirable for production in various trades, that requires determination with the same care that has been bestowed on determining the recognised standards of artificial illumination.

There is need for a considerable investigation into these daylight requirements of various occupations; one method of approach to which would be the statistical measurement of output by workers so engaged that their output was governed by no other variable factor. Experience of physiological experimentation in industry has shown that such a condition is practically unobtainable in a works: there are always so many outside influences masking the effects that it is attempted to measure.

It is to be hoped that, after the war, some such research as that indicated above may be initiated and that the society will be concerned therewith.

Dr. J. W. T. Walsh, replying to the discussion, said that the comments made and the contributions that had been promised would, he felt sure, be of great use to those who would be considering the problems of daylighting in the immediate future.

Commenting on Mr. Waldram's remarks, he said that it was owing to the necessity for keeping the paper to a

reasonable length that he had not been able to deal more adequately with the subject of fenestration and of building regulations. It had been necessary to deal with these matters generally, and this might have had the unfortunate effect of conveying the impression that they were much simpler than was really the case. He wanted to point out that the paper dealt exclusively with the planning of new buildings and was not in any way concerned with buildings already in existence; even with this limitation it had, as Mr. Waldram indicated, been impossible to refer to all the work which had been done on the subject of daylighting during the last two or three decades.

Dr. Walsh regretted that Mr. Waldram should regard some of the values he quoted as outside practical politics. While agreeing that no standard should be accepted until its soundness had been thoroughly established, he felt that a daylight factor of 1 per cent. for schools was not unreasonable, and as regards the 5 per cent. for factories this was fairly easily obtainable in a roof-lighted building, and so might well be adopted as a standard for new construction. Possibly the provision of one hour's sunshine in mid-winter would prove to be impracticable in urban areas. Table III. was, as stated in the paper, put forward by the British National Illumination Committee as a basis for discussion and had never been approved by the I.C.I. Mr. Waldram was correct in saying that the L.C.C. method of defining obstruction by height and angle was equivalent to his method of definition by height and distance, and both were open to the objection mentioned in the paper.

The 0.18 per cent. daylight factor referred to by Mr. Waldram was obtained for the conditions stated in the paper (see p. 22), assuming that the building obstructed was sufficiently far from the obstruction to cause no serious diminution of the brightness of the latter, from the top down to the level of the obstructed window. This assumption would quite frequently be unwarranted, but it was made to simplify the calculation for a purely illustrative example. The section on Insolation should certainly have contained a reference to the Report mentioned by Mr. Waldram. This report could be found in the R.I.B.A. Journal, Vol. 39, 1932, p. 777.

Mr. Dufton had mentioned that the increasing value of a given window area with increase of height was only true to a limit, which he put at about 30°. This was quite true and the statement in the paper was in accordance with this implicitly, though not explicitly, since it considered only rooms of ordinary dimensions and was a general statement as regards points at some distance from the window. Mr. Dufton's limit, for example, would exclude points less than 10 feet from the window in the case of a window head of 8 feet.

Mr. Markham had rightly pointed out that the width of the window was not without influence; throughout the paper the tacit assumption had been made that the rooms and windows would be of dimensions commonly met with in ordinary domestic or office buildings. As regards orientation, reference should be made to the report mentioned by Mr. Waldram and referred to above.

The distinction between geometric and photometric daylight factors, referred to by Mr. Beckett, was certainly important, and it was allowed for in all modern methods of computation so far as the effect of the window glass was concerned. The effect of internal reflections was so dependent on the whim of the occupier that it was safer to ignore it altogether. If this was done the adoption of a light internal decoration brought the occupier his reward in the form of an illumination bonus, especially at the back of the room.

Mr. Ackermann's suggestion of "isophotal line" had already been adopted by the I.C.I. in its vocabulary, where "isophot curve" was given as an alternative to "equilux curve" for a line of constant illumination. That, however, could not very well be used for a line of constant daylight factor. Mr. Ackermann's skymeter dealt, of course, with existing buildings, whereas the paper was concerned only with buildings at the planning stage.

Mr. Allen's criticism of the standards put forward in 1931 was very timely. The subject was one of considerable difficulty, and no doubt it would require careful consideration by a number of architects and illuminating engineers if a satisfactory system was to be devised. The diagrams of kitchens shown by Mr. Allen were of great interest, and it was most heartening to find that, for once, the requirements in domestic buildings were receiving proper consideration. In the past far too much attention had been paid to other types of buildings and too little to the homes of the people so far as daylight was concerned.

Mr. Dow's remarks about internal decoration were to a certain extent covered by the reply to Mr. Beckett, but it was certainly important that in some way people should be urged to adopt light colours for internal decoration. On the admission of sunlight different people would hold different views, but one could always adopt Mr. Dow's method of dealing with an excess, whereas a deficiency was incurable. Dr. Angus's endorsement of the necessity for further investigation of the daylight requirements for different processes was very encouraging. Such investigations were often extremely laborious and had to be continued for considerable periods of time to get reliable results, and measurements of output often did not tell the whole story. In this connection Dr. Walsh felt he would like to refer to his opening remark. Daylight, he claimed, was an amenity to be provided for its own sake quite as much as for its value in increasing efficiency or for any other utilitarian consideration.

## New Centre and Group

A request has been made on behalf of the newly-formed Group in the North-Eastern Area for formal recognition as a Centre next Session and has been approved by the Council. The change in status will take effect from October 1 next, when the new Session opens, but any financial changes in regard to subscriptions, etc., will not operate until the commencement of the new financial year on January 1, 1943.

Following a meeting held in Bristol on January 30, which was addressed by the President, a request has also been conveyed to the Council for the recognition of a "Group" in this district, for which Mr. D. J. Sawkins has been acting as honorary secretary. This request has likewise been approved, and the names of officers and committee will be announced in due course.

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."*

# ELECTION OF OFFICERS AND COUNCIL

## SESSION 1942-1943. OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, and Ordinary Members of Council, is presented below for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48) :—

> "After the issue of the Council's list, and not later than the *15th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nominations in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

### Present Officers and Members of Council

***President*** :—*Mr. W. J. Jones*, M.Sc., M.I.E.E., F.I.E.S.

***Past Presidents*** :—

Mr. A. P. TROTTER, M.INST.C.E., F.I.E.S.
Sir JOHN HERBERT PARSONS, C.B.E., F.R.S., F.I.E.S.
Sir DUNCAN WILSON, C.V.O., C.B.E., F.I.E.S.
Dr. C. C. PATERSON, O.B.E., M.INST.C.E., M.I.E.E., F.I.E.S.
Dr. J. W. T. WALSH, M.A., M.I.E.E., F.I.E.S.
Lt.-Col. K. EDGCUMBE, T.D., M.INST.C.E., M.I.E.E., F.I.E.S.
Lt.-Com. HAYDN T. HARRISON, Mr. C. W. SULLY. [M.I.E.E., R.N.V.R., F.I.E.S.
Mr. H. HEPWORTH THOMPSON.
Mr. A. W. BEUTTELL, M.I.E.E., F.I.E.S.
Mr. A. CUNNINGTON, B.SC., M.I.E.E., F.I.E.S.
Dr. S. ENGLISH, F.I.C., F.INST.P., F.I.E.S.
Mr. PERCY GOOD, M.I.E.E., F.I.C.G., F.I.E.S.
Mr. F. C. SMITH, M.INST.GAS E., F.I.E.S.
PROFESSOR J. T. MACGREGOR-MORRIS, D.SC., M.I.E.E., F.I.E.S.

***Vice-Presidents*** :—

*Mr. R. O. Ackerley*, F.I.E.S. (1939)
*Dr. H. Buckley*, F.INST.P., F.I.E.S. (1940)
*Mr. E. J. Stewart*, M.A., B.SC., F.I.E.S. (1940)

***Members of Council*** :—

Mr. T. CATTEN (1941)
*Mr. Dean Chandler* (1939)
Mr. R. W. DANIEL (1940)
Mr. G. DIXON (1940)
*Mr. W. J. Edwards* (1939)
Mr. N. V. EVERTON (1940)
Mr. G. W. GOLDS (1940)
*Mr. C. E. Greenslade* (1939)
Dr. W. M. HAMPTON (1941)
Mr. J. W. HOWELL (1941)
*Mr. H. Lingard* (1939)
Mr. HOWARD LONG (1940)
Mr. R. MAXTED (1940)
Mr. C. W. M. PHILLIPS (1940)
Mr. W. F. POGSON (1941)
Mr. J. S. PRESTON (1941)
*Mr. T. E. Ritchie* (1939)
Mr. E. B. SAWYER (1941)
*Mr. K. F. Sawyer* (1939)
*Mr. E. Stroud* (1940)
Mr. CRAWFORD SUGG (1941)
Mr. J. M. WALDRAM (1940)
*Mr. H. C. Weston* (1941)
Dr. W. D. WRIGHT (1941)

***Chairmen of Centres*** (ex-officio) :—

Mr. W. HETHERINGTON (North Midland)
Mr. J. TAYLOR (North Western)
Mr. E. J. STEWART (Scottish)
Mr. P. J. WATSON (Midland)
Mr. M. WADESON (Nottingham)

***Hon. Secretary*** :—*Mr. J. Stewart Dow* (1928)
***Hon. Treasurer*** :—*Mr. E. W. Murray* (1939)

The names in italics are those of retiring Officers or Members. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

### Nominated by the Council to fill Vacancies

***President*** :—

Mr. R. O. ACKERLEY, F.I.E.S.

***Vice-Presidents*** :—

Dr. H. BUCKLEY, F.INST.P., F.I.E.S. (1940)
Mr. E. J. STEWART, M.A., B.SC., F.I.E.S. (1940)
Mr. E. STROUD, F.I.E.S.

***Members of Council*** :—

Mr. H. S. ALLPRESS
Mr. J. B. CARNE
Mr. S. I. ELLIS
Mr. W. HETHERINGTON
Mr. F. F. MIDDLETON
Mr. E. G. PHILLIPS
Mr. R. P. SAYERS
Mr. W. R. STEVENS

***Hon. Secretary*** :—Mr. J. STEWART DOW
***Hon. Treasurer*** :—Mr. H. C. WESTON

### Sessional Meetings in London.

A Sessional Meeting was held on Tuesday, January 13, at 2.30 p.m., when the chair was taken by the President (Mr. W. J. Jones).

After the Minutes of the last meeting had been taken as read the Chairman called upon Dr. J. W. T. Walsh to present his paper on "Planning for Daylight." An interesting discussion ensued, in which the following took part: Mr. P. J. Waldram, Mr. A. F. Dufton (Building Research Station), Mr. J. Markham (Ministry of Works and Buildings), Mr. Edwin Williams (L.C.C. Architects' Department), Mr. H. E. Beckett (Ministry of Home Security), Mr. A. S. E. Ackermann, Mr. W. Allen (Building Research Station), Mr. W. J. Jones (President), and Mr. J. S. Dow (Hon. Secretary).

At a subsequent meeting on February 10, when, in the absence of the President, Mr. R. O. Ackerley presided, the following series of problems was presented and discussed:

The Location of Fluorescent Tubular Lamps with Respect to the Object Illuminated (Mr. M. W. Peirce).

Gas Lighting Under Low-Pressure Conditions (Mr. F. C. Smith).

The Lighting of Station Names and Platforms Under Black-out Conditions (Mr. G. W. Golds).

Convenient Methods of Dimming Lamps on Demand (Mr. H. Bright).

The Measurement of Transmission Factors of Diffusing Materials (Dr. H. Buckley).

Atmospheric Absorbtion in Factories (Mr. E. B. Sawyer).

Lighting and Decoration of Cabins in Passenger Aircraft (Mr. R. Dawe).

Both meetings took place in the lecture theatre of the E.L.M.A. Lighting Service Bureau (2, Savoy-hill, London, W.C.), and the votes of thanks accorded to the authors were coupled with expressions of appreciation of the hospitality of the Bureau.

## Forthcoming Meetings

**March 10th.** A Discussion on **Advance Planning in Lighting Reconstruction** will be opened by MR. HOWARD ROBERTSON, F.R.I.B.A., S.A.D.G. *(Sessional Meeting to be held at the House of the Royal Society of Arts, 6-8, John Adam-street, Adelphi, London, W.C.2).* **2.30 p.m.**

This meeting will be preceded by a meeting of the National Illumination Committee at 2 p.m., and light refreshments will be provided during 1.15 to 2 p.m.

**March 9th.** MR. F. L. WARBURTON, M.Sc., A.R.C.S., A.Inst.P., on **Colorimetry.** *(Meeting of North Midland Centre, at the Gt. Northern Station Hotel, Leeds).* **3 p.m.**

**March 10th.** Replies to **Questions on Lighting Topics** *(Meeting of the Bath (West of England) Group).*

**March 12th.** DR. W. J. WELLWOOD FERGUSON on **Colour Vision** *(Meeting of North-Western Centre, at the Manchester College of Technology, Sackville-street, Manchester).* **2.30 p.m.**

By kind invitation of the Institution of Electrical Engineers, members of the Society may attend the meeting of the Installations Section, at Savoy-place, London, W.C.2, on April 16, when a paper on "Fluorescent Lamps" by Messrs. L. J. Davies and W. J. Ruff will be read. The meeting will commence at 6 p.m. (tea at 4.30 p.m.). No application for tickets need be made, and signature of the attendance register will be sufficient.

### Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society and their names have been added to the list of members*:

CORPORATE MEMBERS:—

| | |
|---|---|
| Barrett, W. | 86, Third Avenue, BATH. |
| Black, A. S. | 71, Waterloo Street, GLASGOW. |
| Briddon, R. J. W. | 164, Rutland Road, West Bridgford, NOTTS. |
| Cook, S. A. | Barrett Bungalow, Sutton Benger, WILTS. |
| Fisher, W. A. | 82, Claremont Avenue, Maghull, W. LANCS. |
| Herring, H. R. | 30, Beech Hill Road, SUTTON COLDFIELD. |
| Jones, T. R. | 19, Church Road, LIVERPOOL, 15. |
| Kelly, R. | "Fernleigh," 13, Sandridge Road, Melksham, WILTS. |
| Laughton, W. A. | 120, Hill View, Henleaze, BRISTOL. |
| Lumsden, J. Harwood | "Mawden," Woodend Lane, Stalybridge, CHESHIRE. |
| Marrison, E. | 57, High Storrs Drive, SHEFFIELD, 11. |
| Marsden, D. | 22, Gisborne Road, SHEFFIELD, 11. |
| Pardow, F. N. | The Rise, Carrwood Avenue, Bramhall, CHESHIRE. |
| Richardson, T. K. | 66, Aigburth Road, LIVERPOOL, 17. |
| Richman, S. M. | "Palmerston," Warminster Road, BATH. |
| Rix, R. R. | 18, Mausfield Road, Clarkston, GLASGOW. |
| Rush, W. | 554, Bath Road, Saltford, Nr. BRISTOL. |
| Skinner, A. J. | 18, Downleaze, Stoke Bishop, BRISTOL, 9. |
| Taylor, A. E. | The General Electric Co., Ltd., 4, Cheap Street, BATH. |
| Thomas, F. C. | c/o Bertram Thomas (Engineers), Ltd., Worsley Street, Hulme, MANCHESTER, 15. |
| Triggs, E. H. | "Leytonia," Fistwood Lane, Totton, HANTS. |
| Vaughan-Shaw, W. | 18, Richmond Hill, Clifton, BRISTOL, 8. |
| Warburton, F. S. | 24, Reevylands Drive, Wibsey, BRADFORD. |
| Whaley, R. S. | 62, Hamilton Avenue, Harborne, BIRMINGHAM, 17. |

ASSOCIATES:—

| | |
|---|---|
| West, J. L. | Chelsea House, Wells Road, BATH. |

### Transfers from Country to Corporate Membership.

| | |
|---|---|
| Beck, F. | "Quilfrey," Royal Oak Road, Quinton, BIRMINGHAM. |
| Fielding, E. C. | "Brendon," Lonsdale Road, WALSALL. |
| Martin, H. E. L. | 220, West Regent Street, GLASGOW, C.2. |
| Montgomery, R. | 112, Evington Road, LEICESTER. |

* In accordance with the present procedure the names of applicants for membership are published in THE TRANSACTIONS as soon as such applications have received the approval of the Council and the subscription for the current year has been duly paid.

# PROBLEMS IN ILLUMINATING ENGINEERING

*(Proceedings at the Sessional Meeting held on February 10th, 1942)*

Mr. R. O. ACKERLEY, who presided in the absence of the President, explained that the meeting was to be devoted to the discussion of a series of problems in illuminating engineering, all in some measure associated with war conditions or with post-war reconstruction.

Seven such problems were dealt with in turn by various authors, and were as follows.

## The Location of Fluorescent Tubular Lamps with Respect to the Object Illuminated

By M. W. Peirce *(Fellow)*

Many installations of fluorescent tubes lend themselves to a symmetrical layout, and such installations in general provide a perfectly satisfactory distribution of light. In cases where shadow effect and directional lighting are of particular importance it is necessary to consider the position of the fitting with respect to the work. Only thus is it possible to take full advantage of the length of the light source in order to give the best possible results.

At mounting heights of about 5 ft. above the plane of work the area of effective illumination is approximately circular in shape, while at lower mounting heights the area is elliptical with the axis parallel

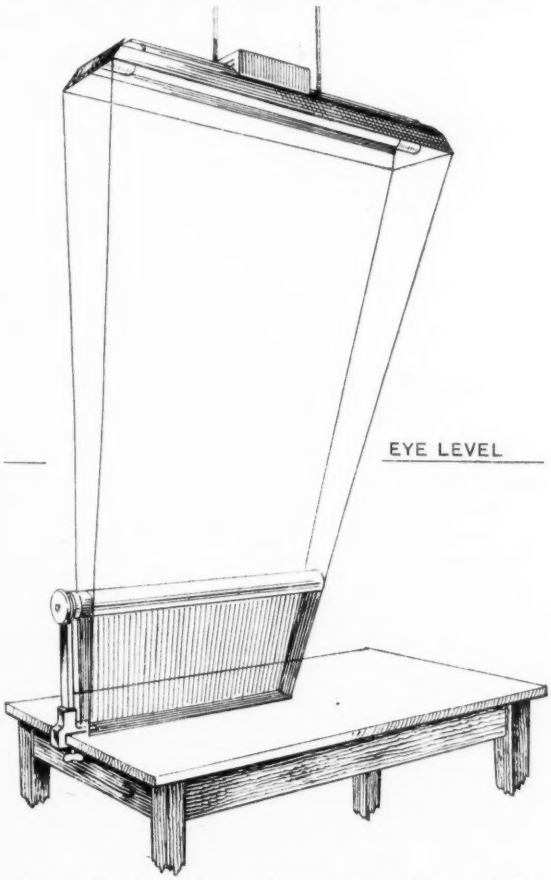



Fig. 1. Showing shadow cast by an elongated object parallel to the tubular source.

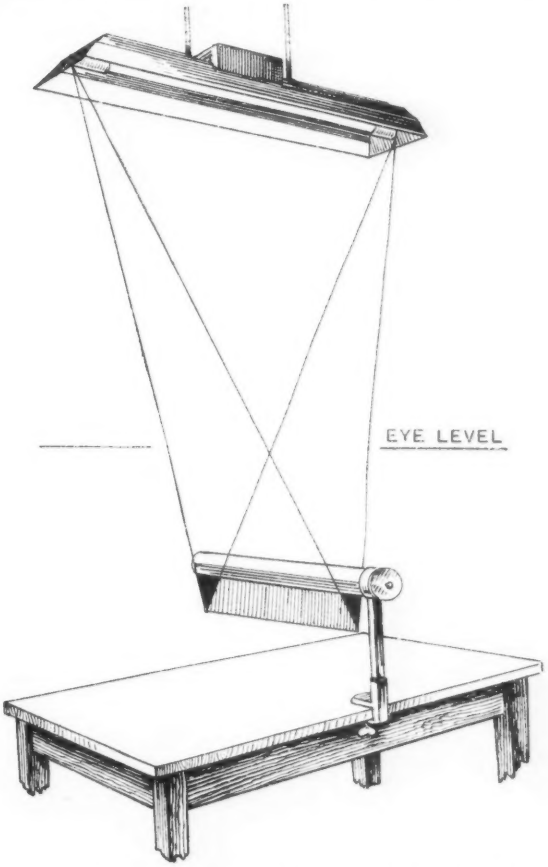



Fig. 2. Showing shadowless effect of objects at right angles to the tubular source.

to the fitting. Thus it is only at low mounting heights that the orientation of the fitting will have any effect on actual illumination values. At the medium mounting heights, therefore, the fitting position can be chosen to give the best directional effect or to reduce shadows.

In cases where shadows are of importance it will be found that while there is practically no shadow of objects at right angles to the line of the source there is considerable shadow of objects lying parallel to the source. Figs. 1 and 2 illustrate this. Even in a very extensive installation an object such as a pencil

will produce multiple shadows if the tubes are run in parallel lines and the pencil is held parallel to the tubes.

A number of possible arrangements of tubes over a bench are indicated in Fig. 3. For a shadowless effect the arrangement with tubes alternately parallel and at right angles to the bench is to be recommended. The oblique arrangements are particularly useful with double-sided benches where directional lighting is required, either from the left or the right of the operative. The arrangement of tubes set at right angles to the bench is always liable to give shadows of the arms of operatives reaching over the bench, but there may be cases where for other reasons this arrangement is desirable.

At very low mounting heights it is desirable to use the fittings parallel to the bench in order to give even illumination along the bench. In this case, however, there is likely to be little shadow effect, as at the low mounting height the width of the reflector is sufficient to soften the line of the shadow (Fig. 4).

The lighting of drawing tables needs special consideration and it is almost essential that one fitting

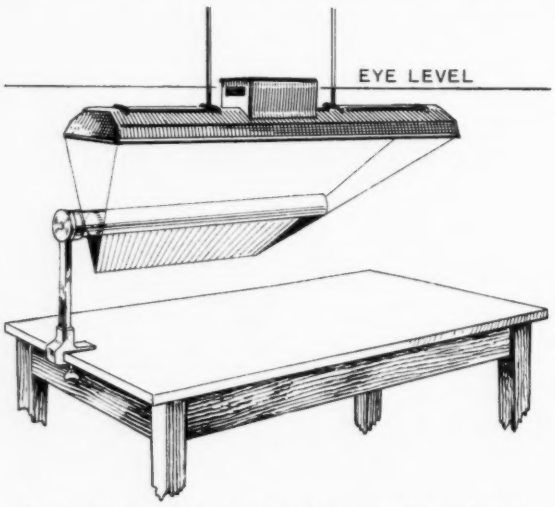
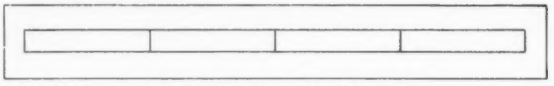
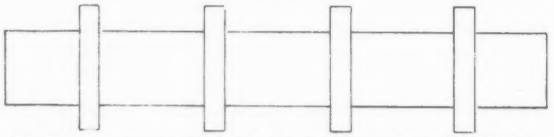



Fig. 4. Showing reduction of shadow due to the width of the reflector at very low mounting height.

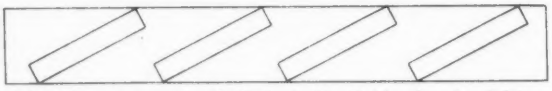
should be allowed per drawing board in order to ensure sufficient light and freedom from shadow and reflected glare. Shadows both of the horizontal "T" square and vertical edge of the set square must be avoided and the oblique arrangement is satisfactory for this purpose. In a large installation, however, there appears to be sufficient build-up of light from adjacent fittings if the units are arranged in lines parallel to the edge of the desks. In large installations where drafting machines are in use with the boards more or less vertical good results have been obtained with the tubes run in lines at right angles to the boards, the lines being arranged slightly to the right of the draughtsmen.



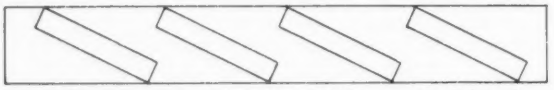
(A). This arrangement is suitable for use where objects do not in general lie parallel with the bench or where "shadowless" effect is not of first importance.



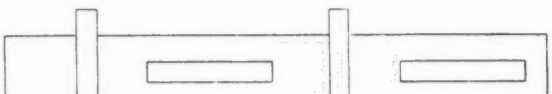
(B). This arrangement diminishes the shadow effect, as compared with (A), but gives shadows of objects lying across the bench and parallel to the tubes.



(C1). This arrangement is suitable for double-sided benches when lighting is required from the left.



(C2). This arrangement is similar to that of (C1), but provides lighting from the right of the worker.



(D). This combination gives a substantially shadowless illumination.

Fig. 3. Showing various arrangements of tubes relative to the area illuminated.

## Gas Lighting Under Low Pressure Conditions

By F. C. Smith, M.Inst.Gas E. *(Fellow)*

The problem may be stated as follows: To ascertain the performance of gas-lighting fittings operated over a range of pressures from 5 to 10 tenths, and to determine the necessary modifications to the burner to ensure acceptable results.

It was further required that the modifications should be of the simplest character, so that any existing installation could be modified with a minimum of expense and inconvenience, and that the installations thus modified to work at these lower pressures should give tolerable results when normal pressure is re-established without change of burner parts. (By "low pressure" is meant a range of pressures from 5 to 10 tenths, and by "normal pressure" 25 to 30 tenths. These pressures are measured directly above the cock control to the lighting fitting.)

A 4-lt. lamp, carrying No. 2 mantles, and of a type representative of fittings used in the great majority

of factories at the present time, was selected for the purpose of experiment.

### Basis of Experiment.

Assuming that no major modifications are made in the burner two lines of approach are possible:—

(1) *Allowing the injector, as drilled for normal pressures, to remain unchanged and working at reduced pressure.*

This involves a reduction in consumption, of the order of 50 per cent. of normal, assuming 8 tenths as the desirable pressure Bijou mantles, with a consumption of 1½ cub. ft. per nozzle may be substituted for No. 2 mantles, consuming approximately 2½ cub. ft. of 500 B.Th.U. gas per nozzle. Only a change of nozzle is necessary.

(2) *Increase in the size of the injector drilling so as to maintain consumption at approximately* 1,250 *B.Th.U. per nozzle.*

In either case the effect of the changes upon air-gas ratio and size of flame may well be considered.

In regard to (1) the air-gas ratio remains fairly constant over a range of pressures until, with diminished pressure, a certain critical point is reached, after which the ratio decreases rapidly, and if carried to the extreme, partially luminous flames will result.

In regard to (2) it can be shown that to maintain the B.Th.U. rate constant at a lower pressure will result in a reduction of the air-gas ratio.*

Both alternatives (1) and (2) were explored in the tests undertaken. A preliminary experiment showed, however, that when the clay discs were removed from the nozzles of the fitting used in the tests, with a view of lowering the resistance of the burner, the lamp operated to greater advantage even under normal conditions. In practice, however, with the usual quality of gas, greater stability can be guaranteed if the discs are retained.

### Results of Tests.

These tests led to the following main conclusions:—

(i.) If open-ended nozzles without clay discs are used (i.e., Modification No. 1) it is possible, at an inlet pressure of 8 tenths, to obtain 45 per cent. of the normal light output with an efficiency of 77.5 per cent. of normal value.

(ii.) If No. 2 open-ended nozzles are used with an injector of diameter 0.088, it is possible to obtain at 8 tenths pressure 97 per cent. of the normal light output with an efficiency slightly in excess of the normal value. (No difficulty is likely to be experienced if the pressure falls to 5 tenths, but the light output will then be 57 per cent., with an efficiency of 85 per cent. of normal value.)

(iii.) If the lamp is subjected to Modification No. 2 and the pressure is raised to normal value (say, 26 to 27 tenths) the light output will be enhanced slightly, but the efficiency reduced to 69 per cent. of normal. The lamp will, however, be noisy and a little unsteady—though not sufficiently so to affect the worker.

If the injector is closed by the manipulation of the injector regulator, light output is increased by about 30 per cent. and efficiency becomes normal, and this performance could be improved by using needle pins of a more tapered variety. Under these conditions the lamps were less noisy and steadiness was improved.

(iv.) A third modification related to grid-end nozzles (which are fitted to the majority of lamps of the pattern studied in the district under consideration). With an injector of the same size as in Modification No. 2, and using a grid-end nozzle without disc, a light output of about 82 per cent. of the normal, with an efficiency of 92 per cent., can be obtained at 8 tenths pressure. The light output at 6 tenths is also tolerable, but the flames become slightly luminous and there is a tendency towards a deposit on the nozzles.

(v.) Preliminary observations have been made with petrol air gas. Although this work has only just been commenced, it appears that Modification No. 2 will enable a tolerable result to be achieved without any other change being necessary.

### Recommendations.

As a result of these tests it was recommended that the injectors should be opened, so that at 8 tenths pressure approximately 85 per cent. of the normal B.Th.U. rate is assured, and that No. 2 open-ended nozzles without discs should be used in place of the grid and nozzles with discs. It is of interest to note that the polar distribution curve is not changed in any way likely to affect the usefulness of any lighting system.

*This can be inferred from the formula, $R=\frac{1,658.5\ A\sqrt{Ha}}{Q\ (r+d)\ (r+1)}$ where $R$=experimentally determined ratio for any one burner of Momentum of Gas Stream/Momentum of Air-Gas mixture, $A$ is the cross-sectional area of the burner in sq. in., $d$ is the density of gas, $Air=1$, $Q$ is the gas rate in cu. ft./hr, $r$ is the air-gas ratio, and $H$ is the gas pressure in inches of water.

## Revealing of Station Names Under Blackout Conditions

By G. W. Golds *(Member)*

The problem of revealing station names during the blackout is linked up with the anterior question of dealing with the names in the daytime. Official regulations limit the size of lettering in station names and do not permit names to be displayed which are visible from a highway; even in daytime it is not easy to display names adequately under these conditions. As the standard of artificial lighting permitted on station platforms is not sufficient to illuminate name tablets normally attached to lamps, other devices have to be adopted.

Internally illuminated signs have been tried, but the limits to brightness and size of lettering on these signs render them visible only at fairly close quarters.

Window blinds must be kept drawn and passengers are generally reluctant to raise the blind or open the door in order to look for illuminated signs, and to be of any use signs would have to be at very close intervals along the platform. Supplementary signs formed by cutting stencils in waiting-room windows and printed slips on lamps for reading at close range have also been tried.

Devices for automatically switching lamps on and off, as an indication of arrival at a station, have been suggested but generally speaking are not satisfactory in practice. It has likewise been suggested that some form of lighting might be attached to the train itself and only switched on when the train is standing at a platform. This is quite sound in theory but presents

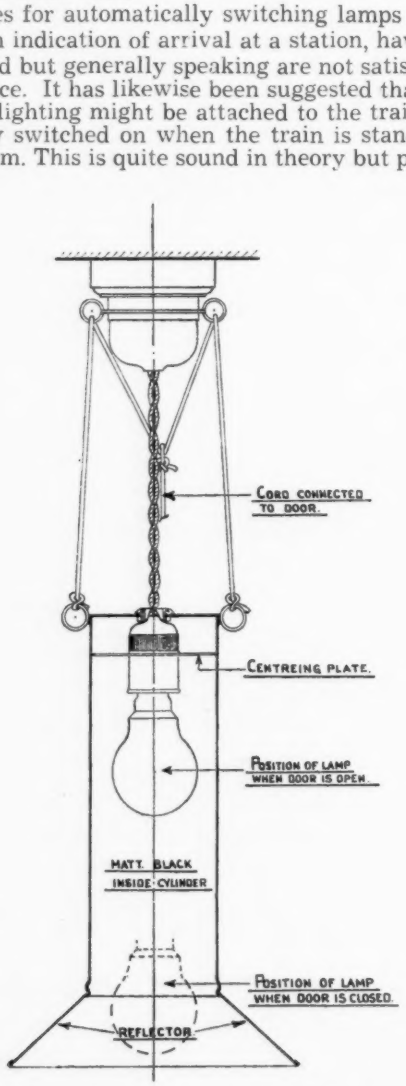

CORD CONNECTED TO DOOR.
CENTREING PLATE.
POSITION OF LAMP WHEN DOOR IS OPEN
MATT. BLACK INSIDE CYLINDER
POSITION OF LAMP WHEN DOOR IS CLOSED
REFLECTOR

Fig. 1. A.R.P. fitting serving as an alternative to a light-trap.

a number of difficulties when put into practice. Both sides of the train would have to be equipped with reflectors and each coach set fitted with a special coupling so that one, two or three units could be used at will and each would have to be capable of individual control from both ends of train involving

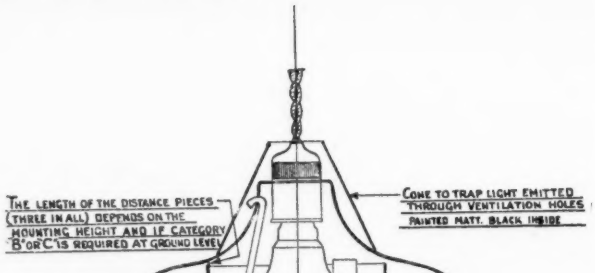

THE LENGTH OF THE DISTANCE PIECES (THREE IN ALL) DEPENDS ON THE MOUNTING HEIGHT AND IF CATEGORY B OR C IS REQUIRED AT GROUND LEVEL
CONE TO TRAP LIGHT EMITTED THROUGH VENTILATION HOLES PAINTED MATT. BLACK INSIDE
BASE CAP (BAYONET FIXING) REMOVABLE FOR MAINTENANCE PURPOSES.

Fig. 2. A.R.P. fitting for category "B" or "C."

complicated switching arrangements. If controlled by a trip from the track difficulties would arise as lights on non-stopping trains would be switched on when the train was passing a station; even if all these difficulties were overcome the maximum lighting permitted on the platform could not be exceeded and little advantage over the present platform lighting could be expected. At present on one railway the white lighting inside the compartments is switched off when train arrives at a station.

A device for showing station names in compartments was actually adopted on the Inner Circle and on City and South London Railway about forty-five years ago, but would of necessity be very complicated on trains running over different routes.

Calling out station names, supplemented by loud speaker equipment at all the principal stations, seems to be the best solution of the problem; in fact the solution may well be found to be one of sound rather than light.

In conclusion Mr. Golds exhibited two fittings which had been specially designed to meet problems in railway lighting in war time.

The first of these (Fig. 1) was designed for use in places like signal boxes, shunters' cabins, etc., where the building of a proper light trap would be difficult or very costly. The reflector is raised or lowered relative to the lamp by the action of opening the door. When the door is open a spot of light is thrown directly under the fitting and normal lighting restored when the door is closed.

The other fitting (Fig. 2) was intended to provide lighting in category "B" or "C." This fitting is designed to attach to existing reflector, giving a large source of low intensity lighting. By adjusting the lengths of the projecting lugs between fitting and reflecting surface a wide range of intensities can be obtained.

## A Convenient Means of Dimming Lights on D.C. Circuits

By Harold Bright, M.A. *(Fellow)*

This device has been found to be of considerable value under war-time conditions. The problem to which it has successfully been applied is as follows:—

A large dockyard is supplied with current at 200 volts d.c., the lighting and power circuits being connected to the same feeders. It is required to dim the dockyard lights to 10 per cent. output without affecting the crane motors and jib spot lights.

At first sight the only solution appears to be by the segregation of the lighting circuits, but the apparatus demonstrated, which is due to Mr. C. H. Nicholson, the District Docks Machinery Engineer, L.N.E.R., and Mr. W. Fordham Cooper, H.M. Electrical Inspector of Factories, provides the solution.

The bulbs in the dockyard lighting fittings, which are of 200-volt pattern, are connected in series with a resistance which may conveniently consist of another similar lamp enclosed in a box. Under these conditions each lamp is burning at half the normal voltage, which is equivalent to about 10 per cent. lumen output. The resistance lamp is shunted by a copper oxide rectifier. When the combination is connected to the mains in one direction the resistance of the rectifier is high, so that the two lamps burn in series as described above. When the polarity is reversed the rectifier offers negligible resistance to the flow of current, so that the resistance lamp is virtually short circuited and the visible lamp then burns at full brightness. Reversing the polarity does not, of course, affect motors or normal lighting equipment.

Another application of the same device was demonstrated. In this case the whole of the lighting circuits are transferred to a 100-volt standby battery, thereby reducing the light output to 10 per cent. Lamp combinations using a rectifier and two 100-volt bulbs can be arranged so as to continue giving the full light output.

## The Measurement of the Transmission Factors of Diffusing Materials

By H. Buckley, D.Sc., F.Inst.P. *(Fellow)*

Just as the war has created interest in the transmission properties of black-out materials so it has created interest in the transmission properties of window substitutes, many of which act as diffusing materials. The transmission properties of interest are those for normally and for diffusely incident light. Very accurate knowledge of these properties is not necessary, so that a simple method of determining them by means of a rectifier photo-cell is quite satisfactory.

For the determination of the transmission factor for normally incident light an electric lamp was set up above a horizontally placed photo-cell covered with a removable mask having an aperture somewhat smaller in area than the active area of the cell.

The transmission factor is obtained from the ratio of the photo-currents obtained with and without the diffusing material inserted between the cell and the mask, if the appropriate correction is applied on account of the interreflection of light which occurs between the cell and the diffusing material. The photo-current, $i_1$, obtained without the insertion of the diffusing material, is proportional to F the incident flux on the cell. The photo-current $i_2$, obtained when the diffusing material is inserted, is proportional to $t\mathrm{F}/(1-\rho_c\ \rho_m)$, where $t$ is the transmission factor of the material and $\rho c$ and $\rho m$ are the reflection factors of the cell and diffusing material respectively, thus

$$t=\frac{i_2}{i_1}(1-\rho_c\ \rho_m).$$

The measured ratio of photo-currents has therefore to be corrected by $\rho_c\ \rho_m$ in order to give the correct value of transmission. The correction is smaller the smaller the reflection factor of the photo-cell. The darkest photo-cell available had a reflection factor of 14 per cent., so that in the measurement of the transmission factors of diffusing materials having reflection factors of 70 per cent. the correction is of the order of 10 per cent.

For the determination of the transmission factor for diffusely incident light, a whitened sphere having three apertures is used as the source of diffused light. This is produced by placing a piece of opal glass in one of the apertures and illuminating it by a lamp close to it. The cell is placed horizontally with its active side downwards on the second aperture situated at the top of the sphere. The third aperture is not required, and is closed by means of black velvet. As before, the transmission factor is obtained from the corrected ratio of the photo-currents obtained with and without the diffusing material placed between the cell and the sphere aperture. In addition to the correction due to interreflection between the cell and the diffusing material a further correction has to be applied, since the insertion of the diffusing material over the cell increases the brightness of the walls of the sphere, so that the incident flux on the material is not F, as it was without the material in position, but $\mathrm{F}(1+\alpha)$, where $\alpha$ is the fractional increase in brightness.

Thus the transmission factor of the diffusing material is given by

$$t=\frac{i_2}{i_1}\frac{1-\rho_c\ \rho_m}{1+\alpha}=\frac{i_2}{i_1}(1-\rho_c\ \rho_m)\ (1-\alpha)\qquad approx.$$

For a sphere 10 in. in diameter having an aperture of 2 in. diameter and a reflection factor of 80 per cent. the increase in brightness of the walls when a material of 70 per cent. reflection factor is placed at the aperture is about 4 per cent. Thus the total correction in certain cases may amount to as much as 14 per cent. The corrections are thus seen to be rather large. They are therefore determined experimentally. A second photo-cell is placed at the third aperture and the increase in brightness of the sphere, due to insertion of the diffusing material, is observed directly as the increase in photo-current in this second

photo-cell. A somewhat similar procedure, in which the current in this second cell is observed with the second aperture open, and then closed with the original photo-cell, the material under test or a sample of known reflection factor, enables the reflection factors $\rho_c$ and $\rho_m$ of the photo-cell and diffusing material to be deducted. Thus the correction $\rho_c \rho_m$ due to interreflection is obtained. Although large, the corrections are quite accurately enough determined in this way.

## Atmospheric Absorption of Light in Factories

By E. B. Sawyer *(Fellow)*

The problem of atmospheric absorption assumes some importance now that the Factories (Standards of Lighting) Regulations require a specific level of illumination as a minimum. In the case of installations in foundries, steel works, etc., where fittings have to be mounted 40 to 60 ft. above the floor, the illumination may, in practice, be found to fall much below calculated values.

Reference was made in the Fourth Report of the Departmental Committee on Lighting in Factories to the need for an allowance of 25 to 50 per cent. in design to allow for loss of light in service due to dust fumes, vapour, and deterioration of fittings and lamps. The allowance for depreciation made by lighting engineers designing electric lighting installations is usually 30 per cent., but this does not seem adequate in such cases as those mentioned above.

There does not seem to be any ready way for the engineer surveying a job to assess the average absorption, although it may be worth while making readings with a photometer as has been done recently in one large works.

What is termed " absorption " is usually a combination of true absorption and " scatter." In order to measure the percentage loss of light and to allow for these two effects, two large test surfaces were used, one black, the other white. The brightness of each surface was measured at a distance of 5 ft. and 40 ft. The reading on the black surface at 40 ft. is taken as a measure of the scatter from the particles in the atmosphere. The percentage loss of light may then be calculated by the aid of the following formula:—

$$\text{Percentage Loss of Light} \frac{(B_5 - B_{40}) \times 100}{B_5}$$

where $B_5$ = brightness difference at 5 ft. and $B_{40}$ = brightness difference at 40 ft.

In some recent tests in a not very thick atmosphere a loss of light of about 13 per cent. was recorded. In a somewhat denser atmosphere, however, and with a mounting height of 50 ft., the loss was as much as 22 per cent.

A further point of interest, to which attention might well be given in the future, is the selective absorption experienced with electric discharge lamps.

## The Lighting of Passenger Aircraft Cabins

By R. Dawe *(Member)*

Post-war air transport passengers will be many. But they will be " cabin'd, cribbed, confined " in necessarily small spaces, perhaps for long periods without opportunity for exercise. They may, in the first period of adaptation, suffer from visual monotony, from mental distress due to claustrophobia, etc., perhaps from physical distress from sudden changes of position caused by atmospheric conditions or due to excessive glare reflected from clouds.

Development of certain illuminating devices would assist in alleviating these discomforts. If a passenger could change the hue of a light source at will, he could shut out cold grey skies by a blind and turn on warm light. Or he could shut out tropical sunshine and turn on a cool light.

When travelling in darkness the cabin might be made to appear larger by spreading, above and beyond the passenger, light of a hue which suggests distance (blue, violet, etc.); warmer light areas being concentrated round the passenger. Many variations might be arranged to induce pleasant sensations which static decoration could never achieve.

Light sources should either be concealed—a difficult task where there is so little available space—or be of very low brightness to avoid giving irritation.

All equipment should be small and light in weight. The light, not the fitting, should be the decorative feature !

## DISCUSSION

Before calling for general discussion, The CHAIRMAN invited speakers to answer a challenge thrown out by Mr. Bright who, when presenting his contribution on the dimming of lamps, had asked members to suggest the method by which he was able so to control the lamps on a D.C. circuit that whilst some of them maintained their original light output the light output of others was reduced to 10 per cent. when necessary.

Mr. W. J. EDWARDS said he imagined the method was to install a metal rectifier in series with the lamps, and for the change in polarity of the mains it would be necessary to use a by-pass resistance across the rectifier to pass a little current. With the current flowing in one direction the rectifier would offer little resistance and the lamps would give practically their normal light, but when the polarity was reversed only the by-passing resistance would allow a current to pass, to give 10 per cent. of the normal light.

Mr. HAROLD BRIGHT agreed that Mr. Edwards's answer was substanially correct. He (Mr. Bright) had demonstrated the arrangement on a small scale by a display of two lamps, both of the same wattage, one being shunted by a rectifier. When the polarity was in one direction, he said, the rectifier offered high resistance, so that, with the two lamps in series, there was 50 per cent. of the line voltage on both lamps, and the light output was reduced to about 10 per cent. of the normal. When the polarity was reversed, the resistance offered by the rectifier dropped to practically zero and one lamp remained at full brilliance.

In practice, he added, the selector units were mounted on the poles with the lamps, which latter were of about 25 watts in the installation with which he was concerned. The units had been in use for a few months, and they had

afforded a solution to a problem which otherwise could have been tackled only by re-wiring.

The CHAIRMAN commented that much could be said on the problem of aircraft lighting, and he hoped there would be an interesting discussion on it.

With regard to the railways, he asked if it would be possible for the railway companies to provide small flapped slits in the blinds over the windows, so that passengers could lift the flaps and look out when arriving at a station, in order to ascertain what station it was. Most people hesitated to lift the blinds, because that meant infringing black-out regulations—and particularly bearing in mind that it was not always easy to fasten the blinds down again.

Mr. F. L. CALVERT, referring to railway platform lighting, remarked that the problem was governed by existing regulations, notably those relating to the size of name-plates. He suggested that it might be possible to indicate the names of stations by initial and terminal letters, just as the names of the home ports of trawlers and drifters were symbolised, in peace time, by lettere on the sails or bows of the vessels. Thus "Lowestoft" might be symbolised by "E.T.," and on railways "Epsom" might be symbolised by "E.M.," Leatherhead by "L.D.," and so on. If such symbols were made out with fairly large letters and were attached to alternate lighting standards on a railway platform regular passengers could identify stations quickly and it would dispose of the difficulty of deaf persons who were unable to hear the names of stations when announced by porters.

Mr. G. W. GOLDS said he was not sure that that proposal had been made to the railway companies; but it had been suggested to him some time ago that it might be possible to identify each station by a number and to print the number of the station on the ticket which was handed to the passenger. That might prove unduly complicated, and there was still the difficulty that the passengers had to look out of the trains in order to see the number of the station, so that it would still be necessary to raise the blinds or to look through slits. Furthermore, the question of cost had to be considered.

At the majority of the suburban stations on the Southern Railway the white lighting in the coaches was switched off when a train arrived at a platform, and the passengers knew that if the lighting was not cut off the train was not at a platform. But, again, whilst regular passengers became accustomed to the system, strangers might have difficulty.

Mr. L. G. APPLEBEE suggested that platforms on the suburban services of surface railways should bear illuminated signs indicating the route of trains in a manner similar to that adopted on underground platforms. He was led to make that suggestion by his own experience. Frequently he entrained at Vauxhall, on the Southern Railway. The conditions there were peculiar, because the ticket examiner was downstairs, and when one reached the platform there was no one whom one could ask the destination of the trains. Usually the man who was calling out the names of the stations served by each train was a long way away, he had a raucous voice, and in any case it was drowned by the noise of the trains. Mr. Applebee also complained that the lighting in some of the rooms used by the public on station platforms was atrocious, and suggested that, even during war-time, improvement could be effected. He was particularly critical of the lighting in conveniences, where usually there was one blue-coated lamp, which appeared to have been dipped thousands of times.

Mr. J. M. WALDRAM gave his experience of the effect of lighting from two fluorescent tubes, in his own small office. There was not room to place the drawing board in the most convenient place in relation to lighting. As matters stood he could draw vertical lines with a set-square and horizontal lines with a T-square, but found it difficult to avoid troublesome shadows from the edge of a ruler, especially in drawing inclined lines. Apparently in such circumstances the fluorescent tubes should not be parallel one to the other, but he would welcome further information on this point.

With regard to transmission of light through smoky atmospheres, the black and white test plate mentioned by Mr. Sawyer resembled one which he himself had adopted in dealing with a similar problem.

The transmission of light through the atmosphere was a matter to which it would be necessary to devote attention after the war, not only in connection with factory bays but in other places; for example, cinemas, where the smoke in the atmosphere often resulted in a considerable loss of light on the screens. Full allowance for atmospheric absorbtion would probably explain many anomalies in photometry.

Discussing the illumination of passenger aircraft cabins, Mr. Waldram inquired whether there would be sufficient power available on post-war aircraft to provide a really high level of illumination, such as could compete with the strong daylight entering the windows during the day. Commenting upon Mr. Dawe's suggestion that the apparent size of a cabin might be increased by the use of light of suitable colour and quality, Mr. Waldram recalled a recent experience of his own. He had been staying in an old house which had been refurnished with old furniture. In his room there was a large wardrobe, placed near a window. The wardrobe was shifted to the back of the room where one did not notice it on entering. The room then appeared to be much bigger than formerly, because the big dark side of the wardrobe which had been in shadow when in its former position, and which had dominated the room, had been removed. Even the maid had commented that the size of the room had been doubled, and that she would have to spend twice as much time dusting it!

Mr. E. W. MURRAY referred to the A.R.P. fitting which Mr. Golds had altered and which had been mentioned in his paper. This enabled the light to be confined to a small area or a larger area, as desired, by merely sliding the lamp up or down a tubular fitting. Mr. Golds had achieved a useful device for illuminating rooms where it was difficult to fit a light trap at the door. Mr. Golds was also to be congratulated on his second fitting. Here the light source was screened by a cap under a dispersive fitting which provided a type of indirect lighting, using the reflector as the illuminant and thus producing a comparatively large area illuminant of low brightness. Such a fitting provided the best form of illuminant for low intensity A.R.P. lighting and avoided the detrimental glare which was obtained with the standard B and $B_1$ fittings. It was a great pity that Mr. Golds was not on the committee responsible for the original designs!

In connection with Mr. Sawyer's remarks regarding the loss of light because of dust in the atmosphere of work rooms, Mr. Murray reminded Mr. Sawyer that under the provision of Section 47, Factories Act, 1937, fumes and dust must not be allowed to accumulate to such an extent as to be injurious or even offensive to the persons employed. At the same time Mr. Murray pointed out that the light loss in the lecture room because of the smoke would not reduce the illumination at reading level to the same extent as would the lack of cleaning of the reflectors and lamps in a factory.

The CHAIRMAN pointed out that Mr. Sawyer had been dealing with the illumination of very high bays in works such as foundries, where the murk was extracted through the roof and where the atmosphere was moving upwards. If the regulations were as stated by Mr. Murray, one could only suggest that the factory inspectors should enforce them.

Mr. J. PALMER suggested, as a tentative solution of the problem of measuring light transmission through dust and fumes, the use of a box having windows on two sides, one illuminated by a lamp and the other having a photo-cell. The box could collect a sample of an atmosphere and could then be closed, the transmission could be measured by the photo-cell, and then the dust and fumes could be precipitated by a jet of water or by something like the Wilson closed chamber. The apparatus could be made transportable, so that it could be taken to a laboratory, where the measurements could be

made, instead of having to make the measurements on the spot.

Mr. J. M. WALDRAM pointed out that the lost light due to atmosphere was an exponential function. He also emphasised the difficulty that if one bottled up a sample of an atmosphere it very soon became different from what it was originally.

Mr. J. F. STANLEY, in a criticism of some of the railway station lighting, said that at the ticket barrier at a certain station which he used there was a fitting which directed a very narrow beam of light downwards; the ticket collector stood in the shadow, and the passengers passed through the beam, which was rather disconcerting, because as they passed through it they could only just detect the figure of the collector and could not see anything beyond the barrier. He recalled that on one occasion, as he approached the station, a train was coming in, and he had arrived at the barrier just as the passengers were streaming through it from the train. The ticket collector was not there. Being unable to get through the barrier against the stream of passengers, Mr. Stanley had lost the train; but he was compensated by the fact that one passenger, mistaking him for the ticket collector had handed him 7½d., with the remark "from Clapham Junction." (Laughter.)

Mr. J. S. Dow, discussing the paper by Mr. Peirce, said he had always felt that, although the fluorescent tube was so great a gift in many ways, the fact that it was available only as a straight tube was rather a drawback. He wondered whether Mr. Peirce could give some hope that after the war there would be other shapes, perhaps symmetrical units in the form of tubes or coils, so that the difficulty with regard to the shadow could be overcome?

It was something of a reproach to modern lighting that we could not satisfactorily dim lights without sacrificing efficiency in so doing, and he hoped that that reproach would be removed in the future. He had been reminded, by the contributions of Mr. Smith and Mr. Bright, that we were still not making progress in that particular direction. In his boyhood days he had worked by the light from flat-flame burners; the simplicity with which those lights could be turned up and down had not yet been rivalled.

Commenting on Mr. Buckley's photometric experiments, he asked whether they had led to any understanding about the standard of transmission through fabrics used for black-out purposes, because that was a subject on which he and others had had some arguments with Wardens. He believed there had been an attempt to define what the maximum transmission through a black curtain must be.

As to atmospheric absorption of light, perhaps Mr. Sawyer could give a closer indication of how dense the atmosphere must be before the absorption made itself felt. For example, could Mr. Sawyer say whether an atmosphere such as that in the meeting room was sufficiently dense to cause any detectable deterioration of lighting, and whether, on a moderate night, its effect on the lighting in the streets would be of considerable consequence?

Turning to the railway lighting problem, Mr. Dow pointed out that whilst in general it might be easier to guide and inform passengers by sound rather than light, the method did not answer for the minority of persons who were deaf, and was liable to be vitiated by inarticulate utterances of porters and loud-speakers. He recalled the ingenious device, in the early days of tube traffic, whereby the names of approaching stations were indicated on falling flaps inside each carriage. It was, however, difficult to ensure absolute reliability of such devices, and if the information they gave was occasionally incorrect the public ceased to feel confidence in them. His attention had been drawn to occasional fatal accidents owing to people mistakenly jumping out of trains when they stopped between stations. It seemed to him that if all platforms were illuminated to 0.002 ft.c., and if a broad white band were invariably provided to indicate the edge of the platform this mistake could hardly occur. It would also help towards the recognition when *some* station had been reached if the vertical background were painted at intervals in a light colour. It seemed reasonable to suggest that permission might well be accorded for name-plates of adequate size, sufficiently illuminated, to be mounted when covered by roofs and canopies so as to shield them from observation from above.

Mr. W. J. EDWARDS, dealing with Mr. Sawyer's problem of the atmospheric absorption of light, recalled an experience he had had in connection with smoke detection, when his object was to ensure that no smoke was drawn in through the fresh air intake fans. It was found that, when there was fog in the atmosphere, the smoke detector would trip the fans. He had had the idea, which had proved to be wrong, that the use of infra-red rays would enable the light to penetrate the fog, so that the fan would not be affected by fog, whilst at the same time the fan would be shut down by smoke. The light had certainly cut through the fog, so that the fog failed to operate the smoke detector; but it had also prevented the smoke detector being operated by smoke. Undoubtedly, fog had a great effect on the light in a factory, particularly where mounting heights were 40 ft. or 50 ft.; he asked whether Mr. Sawyer could give data concerning the loss of light due to natural fog.

Again, he wondered whether, if an infra-red screen were used to make comparisons between smoky and normal atmospheres, it might be found that a smoky atmosphere had so little effect on the infra-red rays that the efficiency of light transmission would be almost the same as for a smokeless atmosphere. If so, this could be used as a gauge for the loss of light for the light source without the infra-red screen.

Finally, he said that, inasmuch as the atmosphere was likely to be worse near the roof of a factory than at lower levels, it seemed that it was wrong to measure the loss of light due to atmosphere at ground level (which was presumably Mr. Sawyer's aim), because it did not take fully into account the loss of light due to atmosphere near the roof.

Mr. F. C. SMITH, commenting on the suggestions made concerning the taking of samples of air precipitating the impurities, and making measurements, said he felt that, whatever was done in that direction, it would be difficult to correlate the actual loss of light with measurements of that kind.

In that connection, however, he recalled some experiments made some years ago at South Kensington by Dr. J. S. Owens, under the auspices of the Smoke Abatement Society. In those experiments certain atmospheres were used; they were not necessarily smoky, but they were not quite transparent. Photographic measurements of the transmission were made, and they were co-ordinated or co-related as best they could be with the results obtained from samples in an instrument known as the Owens dust counter. That, of course, could not provide a complete answer to the problem with which Mr. Sawyer was dealing, but very likely it would put him on the track towards a solution.

One might use a simple instrument, such as the Owens dust counter, and then from experience one could get an idea as to the corrections that should be made, whether 5, 10, or 20 per cent. Probably that order of accuracy would be quite sufficient, because there was so much variation in atmospheres. He suggested to Mr. Sawyer, therefore, that reference to the Transactions of the Smoke Abatement Society, in which those experiments were described, might help him.

Mr. A. CUNNINGTON, dealing with the scheme described by Mr. Bright, asked whether the reversing of polarity was done locally or at some central point. If at the latter, it disposed very simply of the difficulty of relying on the control of reduced lighting by individuals who might be temporarily absent from duty just at the time the warning was received. The scheme was also particularly useful in enabling one to single out certain lamps for reduction while others (possibly in enclosed premises) were not subject to such reduction.

Having been brought up more or less as a railway "baiter," he had some sympathy with those members who had brought forward some of their grumbles regarding the operation of railways, but it was surprising how a little inside knowledge altered one's attitude towards some of the complaints that were made. The factor which amazed him was that there was still so many people travelling on

the railways who did not take even the most elementary precautions for their own safety. They would travel without torches on the blackest of nights, and apparently did not read or listen to instructions. The railway companies naturally could not legislate for such exceptional cases, and had to act on the assumption that they were dealing with sensible people. There were advantages in the uses of sound for the guidance of travellers, although, admittedly, it might be awkward for those who suffered from deafness. Loud speaker equipment could be used effectively for many purposes in addition to the announcement of station names; thus at junctions it could be applied to inform travellers how to reach their destinations, to give them black-out instructions, to remind them to close train doors, and so on.

Perhaps a still better solution of the problem was by neither sound nor light, but by the appeal of the publicity department to regular travellers to help strangers. About 90 per cent. of suburban passengers during blackout hours were familiar with the routes, and the hints they could give to strangers were of more help than many of the ingenious devices which might be introduced.

Mr. M. W. PEIRCE, replying to Mr. Waldram's reference to the use of two fluorescent tubes for the lighting of his office, said the parallel arrangement of the tubes would not necessarily give the best results. A "T" formation would probably be better for the lighting of the drawing-board, the use of a fitting having an opal glass screen under the lamp should give sufficient diffusion to eliminate inconvenient shadows. In reply to Mr. Dow, he did not think the length of the fluorescent tube should be regarded as a disadvantage. It was doubtless possible to bend it to all sorts of shapes without interfering with the discharge; so that possibly after the war there might be many alternatives, the lamps being fashioned into the shapes of letters, and so on. With the tubes as they existed at present one could arrange them into patterns or shapes forming combinations which would give the desired results.

There was room for more discussion on the use of fluorescent tubes. He was afraid we were a little too apt to use tubular lamps over a bench in the form of a strip or in an arrangement which looked satisfactory on a plan. It was quite a different matter, however, if one considered the lighting, not so much in terms of foot-candles, but as a directional lighting installation.

Mr. E. B. SAWYER said that at present it was hardly possible to state the depth of atmosphere in a room likely to cause material absorption; so much depended on the nature and extent of fumes; perhaps in course of time a chart indicating degrees of density might be prepared. In thanking Mr. Smith for his remarks on experiments with the Owens dust counter, he raised the question how far results obtained in different types of atmospheres were comparable. Central station engineers used a device enabling the carbon content of smoke to be estimated. Possibly a similar device might enable the thickness of atmosphere in a factory to be assessed. It was true that the regulations did not permit fumes and smoke in factories, but in many cases, in a foundry, for example, they could not be removed at the source. In blacked-out factories accumulation of smoke which could not readily escape might prove a difficult problem.

Mr. HAROLD BRIGHT, replying to a question concerning the control of the dimming of the lights on the cranes in the installation he had mentioned, said that the control was from a central point. So far as the crane motors were concerned, the direction of rotation was not affected.

Dr. H. BUCKLEY said he could not answer Mr. Dow's question concerning a standard transmission factor through materials used for black-out purposes; he believed the regulations demanded that black-out materials must be "opaque."

Mr. STANLEY pointed out that BS/ARP 23, which was concerned with black-out materials, provided that not more than 0.001 per cent. (one-thousandth part) of the incident light must be allowed to pass through the materials. There was a standard test.

Mr. R. DAWE, answering Mr. Waldram's question as to the power that would be available in post-war passenger aircraft for the provision of illumination, said the problem he had in mind was that of providing illumination for night travelling; he did not think we could compete with daylight yet.

## Sessional Meeting in London.

A Sessional Meeting was held on Tuesday, March 10, at 2.30 p.m., when the chair was taken by the President (Mr. W. J. Jones).

A discussion on "Advance Planning and Lighting Reconstruction" was initiated by Mr. Howard Robertson, F.R.I.B.A., who reviewed the policy to be followed in connection with lighting during the after-war period. He emphasised the necessity for co-operation between the architect and the lighting expert, and suggested the appointment, under the Ministry of Works and Planning, of a Director of Illumination, who should be aided by a small panel of qualified men from the illuminating and architectural professions.

A discussion ensued, in which the following took part: Mr. Grey Wornum, Mr. J. Markham (Ministry of Works and Buildings), Mr. R. O. Ackerley, Mr. Ralph Tubbs, Mr. W. Allen, Mr. D. W. Durrant, Mr. T. Burnett, Mr. W. Watson, Mr. R. F. Taylor, Mr. Brian Peake, Mr. H. E. Beckett, Mr. J. Windham, Mr. P. Good, and Mr. L. G. Applebee.

Mr. Howard Robertson, having briefly replied to the discussion, was accorded a cordial vote of thanks for his address. In conclusion, appreciation was expressed by the Chairman of the hospitality of the Royal Society of Arts.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members.*

CORPORATE MEMBERS:—

Arnot, S. C. .....Metropolitan Vickers Electrical Co., Ltd., 26, Tennant Street, STOCKTON-ON-TEES.

Buttrum, A. B. .....The "Willows," Attenborough, NOTTS.

Faulkner, A. H. .....10, Devonshire Buildings, BATH.

Gorman, W. H. .....Foxcote," Bradford - on - Tone, TAUNTON.

Mackenzie, R. .....9, Vicarage Road, King's Heath, BIRMINGHAM, 14.

Wilson, H. A. .....The Bungalow, Mortomley Lane, High Green, Near SHEFFIELD.

Williams, L. R. .....7, Angel Street, Bridgend, GLAM.

ASSOCIATES:—

West, H. H. .....1, Cambridge Terrace, Widcombe Hill, Bath.

STUDENT MEMBERS:—

Morse, J. W. .....5, Beverley Gardens, Wembley, MIDDX.

* In accordance with the present procedure the names of applicants for membership are published in THE TRANSACTIONS as soon as such applications have received the approval of the Council and the subscription for the current year has been duly paid.

### Annual General Meeting.

Notice is hereby given that the **Annual General Meeting** of the Illuminating Engineering Society will be held at **5 p.m.** on **Tuesday, May 12,** in the Lecture Theatre of the Institution of Mechanical Engineers (Storey's Gate, Westminster, S.W.1), when the Report of the Council and the Accounts for the past year will be presented, and the auditors for the forthcoming year will be elected.

## Forthcoming Sessional and Other Meetings

**April 14th.** Mr. J. N. Aldington on **Fluorescent Light Sources and their Applications.** *(I.E.S. Sessional Meeting to be held at the E.L.M.A. Lighting Service Bureau, 2 Savoy Hill, London, W.C.2).* **5 p.m.**

**April 16th.** Mr. L. J. Davies and Mr. W. J. Ruff on **Fluorescent Lamps.** *(Meeting of the Installations Section of the Institution of Electrical Engineers at Savoy Place, London, W.C 2; I.E.S. members are cordially invited).* **6 p.m.** (Tea at **4.30 p.m.**).

**April 9th.** Mr. W. J. Jones on **Light and Lighting; A Forward Outlook.** *(Meeting of the I.E.S. South Wales Group to take place at the Swansea Technical College, Swansea).* **4 p.m.**

**April 13th.** Mr. W. J. Wellwood Ferguson on **Light Adaptation, with special reference to Working Conditions.** *(Meeting of the I.E.S. North Midland Centre, at the College of Technology, Cookridge-street, Leeds).* **3 p.m.**

**April 17th. Annual General Meeting,** to be followed by an Address on **The Eye** by Dr. J. R. Mitchell (School Medical Officer for Birmingham). *(Meeting of the I.E.S. Midland Centre, at the Imperial Hotel, Temple-street, Birmingham).* **6 p.m.**

**May 12th.** Mr. G. H. Wilson on **Street Lighting, Past, Present and Future.** *(I.E.S. Sessional Meeting to follow the Annual General Meeting, in the Lecture Theatre of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1).* **5 p.m.**

**May 15th.** Mr. C. F. Partridge on **Lighting Terminology.** *(Meeting of the I.E.S. Midland Centre, at the Imperial Hotel, Temple-street, Birmingham).* **6 p.m.**

## NOTES ON RECENT MEETINGS AND EVENTS

At a meeting of the **Nottingham Centre,** held on February 27, Mr. R. Gillespie Williams gave a lecture on "The Poetry of Light," a subject of interest in connection with post-war reconstruction, though it was explained that the lecturer was at present exclusively engaged on work of national importance and unable to follow such peacetime pursuits as the use of colour for display and stage lighting. Mr. Williams devoted some attention to the conception of "animated colour," and described novel applications of coloured light in shops and stores, hotels, restaurants and theatres, etc. His ideas were illustrated by a number of pleasing experiments and demonstrations, on a stage fitted up for the occasion with lighting and control equipment loaned by Messrs. W. J. Furse and Co., Ltd. The address was heard with keen interest and led to an interesting discussion. In the course of the proceedings the Chairman (Mr. M. Wadeson) presented to Mr. C. S. Caunt a copy of "Jane's Fighting Ships," in recognition of his able work as honorary secretary of the Centre. Mr. Caunt, in acknowledging this gift, recalled that he had served in the ranks of the Royal Navy for ten years, and remarked that no more appropriate way of recompensing his efforts could have been found.

On February 24 the President (Mr. W. J. Jones) delivered an address to a meeting of the **Bath Group,** held at the Bath Electricity Showrooms. Taking for his subject "Light and Lighting: a Forward Outlook," he outlined the aims of the I.E.S., its contribution to war effort in connection with A.R.P. lighting problems, and the survey it was now conducting into the part to be played by lighting in post-war reconstruction. Mr. Jones also reviewed recent developments in electric lighting, and showed lantern slides illustrating the application of fluorescent lamps, the possibilities of architectural lighting, etc. An interesting discussion ensued, in which Councillor Barrett, Mr. J. B. Harris, Mr. R. E. Tucker, Mr. W. Allen, and others took part. In conclusion votes of thanks to the president, the chairman (Councillor Barrett), and the Bath Electricity Department were moved by Mr. Catten and were carried with acclamation.

The final meeting of the session of the **North Western Centre** was held in Manchester on March 13, when Mr. W. J. Wellgood Ferguson gave an address on "Colour Vision." Mr. Ferguson is also lecturing to the **North Midland Centre** on April 13.

The **South Wales Group,** which has arranged a series of meetings in Cardiff, is now breaking ground in other cities. A meeting, to be addressed by Mr. R. O. Ackerley, was arranged to take place in Newport on March 19, and on April 9 the President is to address a similar gathering in Swansea.

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."*

# REPORT OF THE COUNCIL FOR THE SESSION OCTOBER, 1941, TO MAY, 1942

*(To be presented at the Annual General Meeting, to take place at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1, at 5 p.m. on Tuesday, May 12th, 1942.)*

During the past session the Society has again been fortunate in being able to carry on its work without interruption, and has continued to hold regular meetings. A feature has been the substantial additions to its membership, largely owing to the activities of the various Centres and to the desire expressed by members, in localities where Centres do not as yet exist, to form groups and hold meetings.

**Election of Officers and Council for Next Session.**

In accordance with the procedure outlined in the Articles and By-Laws of the Society, the nominations made by the Council to fill vacancies have been printed in THE TRANSACTIONS of the Society, and corporate members have thus been afforded an opportunity of making additional nominations. No new nominations having been received in regard to officers of the Society, the proposals of the Council become effective.

Accordingly, Mr. R. O. Ackerley will become president, Dr. H. Buckley, and Mr. E. J. Stewart will continue in office as vice-presidents, and the new vice-president will be Mr. E. Stroud. Mr. J. S. Dow will continue to act as honorary secretary, and Mr. H. C. Weston will become honorary treasurer in succession to Mr. E. W. Murray, whose services during the past three years are recorded with grateful appreciation.

No new nominations having been received for membership of the Council, the proposals of the Council in this connection also become effective, and the members to fill the existing eight vacancies will be as follows:—

Mr. H. S. Allpress, Mr. J. B. Carne, Mr. S. I. Ellis, Mr. W. Hetherington, Mr. F. F. Middleton, Mr. E. G. Phillips, Mr. R. P. Sayers, and Mr. W. R. Stevens.

**Work of Committees.**

In view of the prevailing conditions and the exceptional demands upon the time of many members, the procedure has been adopted during the past session of investing the *General Purposes Committee* with executive powers. This committee was constituted as follows:—

Mr. W. J. Jones (president), Mr. E. W. Murray (hon. treasurer), Mr. J. S. Dow (hon. secretary), Mr. R. O. Ackerley, Dr. H. Buckley, Mr. E. J. Stewart (vice-presidents), Mr. F. C. Smith, Professor J. T. MacGregor-Morris (past presidents). *Co-opted members*: Mr. A. Cunnington, Dr. S. English, and Mr. E. Stroud.

This committee has served its purpose in dealing quickly with all essential questions and reporting at suitable intervals to the Council, which has continued to meet, but at somewhat less frequent intervals than in normal circumstances.

The *Papers Committee* was constituted as follows: Dr. H. Buckley (chairman), Mr. C. E. Greenslade, Dr. W. M. Hampton, Mr. R. Maxted, Mr. E. B. Sawyer, Mr. F. C. Smith, and Dr. W. D. Wright.

The committee has initiated an interesting series of events for the past session and is now engaged in preparing the programme for 1942-43.

A new departure, following the conferences of representatives of Centres held last year, has been the appointment of the *Committee on Centres*, which deals with all matters of common interest to Centres and Groups.

The committee is composed of three representatives of the Council and a representative of each of the five Centres. The Council's representatives during the past session have been Mr. R. O. Ackerley, Mr. N. V. Everton, and Mr. F. C. Smith.

Reference is made below to the activities of this new committee, which has done excellent work.

In addition, in order to give effect to the resolution taken at the Sessional Meeting on May 13, 1941, a special *ad hoc committee* was formed to consider *lighting problems involved in post-war reconstruction.*

This committee was constituted as follows:—Mr. R. O. Ackerley (chairman), Mr. Dean Chandler, Dr. S. English, Mr. Percy Good, Mr. W. J. Jones, Dr. C. C. Paterson, Mr. F. C. Smith, Dr. J. W. T. Walsh, and Sir Duncan Wilson.

Two sub-committees operating under this main committee have been formed. Allusion to their activities is made later on in this Report.

**Centres and Groups.**

As indicated at the commencement of this Report, there has been marked activity by the various Centres of the Society, all of which have now applied for, and received, official recognition, and, in addition, a number of groups of members holding regular meetings have been established. Members have been kept informed of these developments through THE TRANSACTIONS, in which particulars of these various organisations and their officers and committees are published monthly.

In addition to the five existing Centres with headquarters in Leeds, Manchester, Birmingham, Nottingham, and Glasgow, there are now six groups operating, in South Wales, the North-Eastern area, Sheffield, Bath, Bristol, and Leicester. The North-Eastern group, although only formed in the autumn of 1941, has already qualified for status as a Centre, which will become operative in the next (1942-43) Session, and it is hoped that in a number of other cases groups will acquire a sufficiently large number of members resident in their respective areas to seek recognition as Centres in the near future.

The organisation of Centres and Groups, and other matters relating to their welfare and development have been the subject of special conferences, held in London in May and in Leeds in July, 1941, as a result

of which the Committee on Centres has been created. One of the first tasks of this committee has been the preparation of a leaflet outlining Procedure for the Formation of Areas, Centres, and Groups, and presenting skeleton local rules for the guidance of officers and committees of these various organisations.

According to the scheme which is now in operation, the first step towards local organisation in situations where no available facilities for meetings exist is the formation of a Group which, in due course, should develop into a Centre. Ultimately, the number of Centres in existence may well become much greater than at present. Therefore, a third stage is visualised—the division of Great Britain into eight regional areas, each having its own Area Committee to supervise the activities of the various Centres within this locality.

These developments have already been responsible for a considerable accession of new members. The proportion of members resident outside London is becoming continually greater. It is natural that this should be reflected in the management of the Society. This is provided for in the rule whereby the chairmen of the various Centres are, during their term of office, ex-officio Members of Council, but it may also be noted that, apart from this provision, four of the eight new members joining the 1942-43 Council are associated with Centres and Groups.

### Meetings During the Past Session.

Interest in the work of the Society has been well maintained. The total number of meetings held during the past session has approached fifty—certainly an encouraging record in the present circumstances. The part to be played by lighting in post-war reconstruction has figured in a number of papers and addresses, but a great variety of topics has been discussed.

Following the Presidential Address on "Light and Lighting: A Forward Outlook," delivered by Mr. W. J. Jones on October 14, five sessional meetings have been held in London. Of these, four were devoted to specific papers, namely, those by Mr. H. C. Weston ("Industrial Lighting in Reconstruction"), Mr. R. Maxted ("Infra-Red Radiation and Equipment"), Dr. J. W. T. Walsh ("Planning for Daylight"), and Mr. J. N. Aldington ("Fluorescent Sources of Light and Their Applications").

One meeting, on February 10, was devoted to a series of short contributions reviewing lighting problems associated either with present conditions or with post-war reconstruction. On March 10 Mr. Howard Robertson initiated a discussion on "Advance Planning and Lighting Reconstruction." Following the annual meeting, on May 12, Mr. G. H. Wilson has consented to deliver an address on "Street Lighting: Past, Present, and Future."

The various Centres and Groups have, without exception, produced useful programmes. The Presidential Address has been repeated on a number of occasions by Mr. W. J. Jones, who has found occasion to visit practically all the Centres and Groups in the course of his term of office, and has thus given substantial encouragement to groups in course of development. Mr. R. O. Ackerley and Mr. H. C. Weston have likewise visited Centres and Groups and delivered addresses on similar lines to contributions previously presented by them in London.

Good results have attended the practice of arranging meetings in cities where, previously, no organised nucleus of members existed. A notable instance has been the series of meetings arranged, in Newcastle-on-Tyne, in connection with the formation of the North-Eastern Area Group, under the ægis of the North Midland Centre. The South Wales Group has been similarly active in organising meetings in Newport and Swansea, following those initially arranged in Cardiff. Most of the local programmes have included one evening devoted to short contributions dealing with a variety of lighting problems. It is also significant that lectures and addresses dealing with the eye and vision have been in general demand.

The expectation that the various Centres would, in course of time, furnish at least a proportion of papers for sessional meetings in London seems likely to be fulfilled. An instance during the past session has been Mr. Aldington's paper, read in London on April 14 but previously presented before the North Western Centre. In particular, papers on problems coming specially within the province of certain centres of industry should become available. It is hoped that work already undertaken in connection with lighting in the textile industries will be fruitful in this respect.

### The Leon Gaster Memorial Premium.

A statement of the income and expenditure of this fund is appended. The tenth award of the premium of ten guineas was made during the past session to Mr. J. G. Holmes for his paper on "The Recognition of Coloured Light Signals," read before the Society on February 11, 1941.

No applications for the Silver Jubilee Commemoration (1934) Award were received during the past session. It is accordingly proposed, with the aid of Centres and Groups, to take steps to make the existance of this award more widely known to students at technical institutions; and likewise to offer, for the next session, a second award similar in all respects except that it will not be confined to members of the Society, but will be open to any student under the age of twenty-six years.

### Publications.

It has been found possible to continue the regular issue of THE TRANSACTIONS in their present form. In addition "Light and Lighting" has continued to prove helpful as an alternative method of disseminating information to members. In this case it has been found expedient, owing to paper shortage, to make a substantial reduction in size, and the journal now appears in a miniature form, but the essential features have been retained and every effort will be

made to ensure that its value and interest to members is maintained.

### Membership.

Since the commencement of the new Session about 180 new members of all classes were added to the list during the period up to March 31, 1942—a record number, which is due very largely to the increasing development of interest in the Society's work in areas served by Centres and Groups. Of these new members approximately 35 per cent. were resident in South Wales and the West of England, 30 per cent. in the North Midland area, and 15 per cent. in the Midlands. There were also, at that date, about seventy cases in which membership had been applied for but the formalities of election were in course of completion.

There are still a number of cases of members, both in this country and abroad, with whom contact has been temporarily lost, and whose addresses cannot be traced. Nevertheless, taking all such factors into consideration, it appears that the total membership on March 31 in this year, including those known to be on Active Service (about 100), now exceeds 1,100. Of this number the great majority, approximately 900, are now Fellows or Corporate Members.

### Revision of By-laws.

It will be recalled that the final draft of the revised by-laws was presented for the inspection of members prior to the annual general meeting, held on May 13, 1941, and was subsequently formally approved at a special extraordinary meeting held for the purpose on June 24, 1941. These by-laws have since been in operation. One new feature, the adoption of a more expeditious method of completing the formalities of election, has already proved of definite benefit.

### Fellowship.

In the course of the past Session fifteen new Fellows have been elected, and the total now stands at ninety-six—rather less than 10 per cent. of the membership of the Society. The Council takes this opportunity of thanking those members who have served on the board for the careful and conscientious manner in which they have discharged their difficult duties.

### Student Membership.

Whilst in present circumstances a rapid growth in this form of membership can hardly be expected, the Council has given expression to the feeling that some steps should be taken to encourage the younger generation, in whose hands the future of illuminating engineering will largely rest, to enter the ranks of the Society. Two steps in this direction have recently been taken: the announcement of a special award open to any student under the age of twenty-six, irrespective of membership in the Society, and the preparation of a leaflet relating to student membership which is being circulated through appropriate channels. It is hoped that in this way some additions to the ranks of students within the Society will be secured.

### Examinations in Illuminating Engineering.

It has, fortunately, again been found possible to hold the examination in Illuminating Engineering initiated by the City of Guilds of London Institute in 1939. Those responsible are to be commended in their enterprise in arranging for the holding of the examinations not only in the intermediate grade but also for the first time in the final grade. In the present circumstances the number of students attending the examination is unfortunately small, but it is hoped that a better response may be secured in the future.

### Financial Position

In the accounts for the past year a new departure has been made by including, in italics at the side, corresponding figures for the financial year previous to that now considered, so as to facilitate a comparison between 1940 and 1941. The receipts from subscriptions again show an increase, the amount received being nearly £150 greater than in the previous year. The total income, for the first time in the history of the Society, exceeds the £2,000 mark.

On the other hand, there has been some increase in expenditure on such items as administration expenses and the operations of Centres and Groups, with the result that the surplus of income over expenditure (approx. £120), though still substantial, is less than in the previous year. In the course of the year an additional £250 has been devoted to the purchase of National Defence Bonds, bringing the total held to £750. Of the other funds there is little new to record. It is of interest to note, however, a further increase in the quotation for Registered 3½ per cent. War Stock, which brings the general value well above the original price of purchase.

### Researches on A.R.P. Lighting

The position in regard to these researches may be said to have reached a position of stability. Certain work of a confidential nature is being continued, but in general there has been little further to bring before the notice of members.

An opportunity of putting on record some of the work which the Society has done in this field was, however, presented by the paper on "Lighting in War Time," read by the Honorary Secretary before the Royal Society of Arts on November 19, 1941, and subsequently included in the journal of that body (December 26, 1941, p. 58).

### The I.E.S. Code.

The "Recommended Values of Illumination," issued by the Society (the so-called I.E.S. Code) have been adopted by the Ministry of Supply, the

Admiralty, and the Ministry of Aircraft Production in applying the Factories (Standards of Lighting) Regulations (1941). A revised version of the Code has recently been issued. In this new edition, in which values for certain industrial processes have been introduced, the general arrangement has been somewhat simplified and improved. A feature of interest has also been the insertion, for the first time, of certain values for the dyeing, woollen and worsted, cotton and hosiery industries, which are derived from useful work conducted by expert committees formed by the North Midland, North-Western and Nottingham Centres.

In present circumstances, since the Code serves as a basis of national lighting requirements, fundamental modifications in its scope and structure cannot well be entertained. It is, however, necessary to give thought to the future. A committee of the Society is already exploring departures which may ultimately afford a more scientific basis for the recommendations in the Code, besides enabling it scope to be extended in order to deal with glare, shadow, and other factors besides illumination which determine the quality of industrial lighting.

### Lighting Problems in Post-War Reconstruction.

It will be recalled that an address was delivered on this subject by Mr. R. O. Ackerley at the sessional meeting on May 13, 1941, when a resolution was passed requesting the Council to initiate the study of these problems.

Subsequently, a representative committee on Lighting and Reconstruction, under the chairmanship of Mr. R. O. Ackerley, was appointed. Two sub-committees, one devoted to technical and the other to legal aspects, have also been formed and have already carried out useful work. The technical sub-committee is engaged in the preparation of a series of pamphlets, one dealing with first principles and others with special aspects of lighting, which it is hoped will prove useful when the time is ripe. The other sub-committee has been exploring existing legislation bearing on lighting, and has already prepared a report on this subject. It is now considering possible recommendations on legislation for the future. In addition the main committee has established contacts with Government Departments and kindred bodies interested in these problems, with a view to securing the sympathetic consideration of illumination and the utilisation of the services of the Society in connection with post-war developments.

### Programme for the Next Session.

The Council has in prospect several interesting contributions for sessional meetings during the coming Session and, in completing the programme, will welcome offers of papers or suggestions for the consideration of the Papers Committee. Wherever possible authors of papers are asked to prepare manuscripts in good time before the opening of the Session in October next, so that ample time may be available to allot dates and to take measures to ensure informative and successful meetings.

A full programme should also be available for the various Centres and Groups, and the total number of meetings held should even exceed those held during the past Session. In particular it is hoped that researches conducted by Centres in connection with lighting as applied to local industries will lead to the preparation of papers of special interest suitable for presentation in London and before other Centres. It is anticipated that researches already conducted by the North Midland Centre, in connection with the textile industries, will bear fruit in this way.

The development of further Groups and Centres in the near future may well be expected. In particular the Council has under consideration the linking of London with new Groups in the South East of England. It is obviously desirable that local organisations should assist one another by the pooling of information and the occasional exchange of lecturers, as is already being done with advantage in some instances.

Investigations in connection with lighting reconstruction will be continued in order that data may be available for consideration by the authorities when the time is ripe, and this aspect will be kept in mind in arranging forthcoming meetings.

In conclusion the Council desires to take this opportunity of again thanking the many members who have devoted time and effort to the Society's welfare, as officers and members of committees, by undertaking secretarial duties, or by otherwise aiding the activities of the past session. A glance at the list of committees responsible for the operations of Centres and Groups, is sufficient to show how rapid has been the extension of this voluntary effort, without which it would be quite impossible to maintain the activities of the Society on their present scale.

W. J. JONES (*President*).
J. S. DOW (*Hon. Secretary*).

## INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1941.

| 1940 | Dr. EXPENDITURE. | £ s. d. | £ s. d. |
|---|---|---|---|
| £ | | | |
| | To Administration Expenses:— | | |
| 350 | Rent and Clerical Assistance | 450 0 0 | |
| 197 | Printing, Stationery, etc. | 120 6 9 | |
| 35 | Duplicating | 55 15 6 | |
| 115 | Postage and Office Expenses | 146 5 5 | |
| | General Meetings in London:— | £ s. d. | |
| 20 | Hire of Halls | 7 8 6 | |
| 24 | Reporting and Lantern Operating | 27 6 0 | |
| 12 | Refreshments | — — — | |
| | | 34 14 6 | |
| | Special Meeting (A.R.P. Lighting):— | | |
| 13 | Cost of Hall | — — — | |
| | Annual Luncheon (in lieu of dinner) | £ s. d. | |
| | Payments | 30 7 0 | |
| | *Less* Receipts | 24 11 6 | |
| 2 | | 5 15 6 | |
| | Local Centres and Groups:— | | |
| | N. Midland Centre— | | |
| | Provision of Subscriptions | £ s. d. 82 18 6 | |
| | Additional Expenditure | 12 1 6 | |
| 67 | | 95 0 0 | |
| | Remittances to other Centres for Expenses of Meetings | 121 19 10 | |
| 83 | | 216 19 10 | |
| 1 | ,, Bank Charges | 11 0 | |
| 10 | ,, Audit Fee | 10 10 0 | |
| | | | 1,040 18 6 |
| | ,, Cost of Printing Transactions, Reprints, Blocks, etc. | 316 6 8 | |
| | *Less* Sales of Reprints | 16 3 11 | |
| 229 | | | 300 2 9 |
| | ,, Illuminating Engineering Publishing Co., Ltd.:— | | |
| 436 | Allocation and Share of Subscriptions | | 466 1 0 |
| 32 | ,, National Illumination Committee | | 32 0 0 |
| 11 | ,, British Standards Institution | | 10 10 0 |
| 5 | ,, Transfer to Leon Gaster Memorial Fund | | — — — |
| 39 | ,, Premium on Deferred Annuity to Staff | | 38 15 3 |
| 16 | ,, Honorarium to Staff | | 30 0 0 |
| | ,, Legal Advice on Revision of By-Laws, etc. | | 42 0 0 |
| 283 | ,, Excess of Income over Expenditure | | 120 2 4 |
| £1,980 | | | £2,080 9 10 |

| 1940 | Cr. INCOME. | £ s. d. |
|---|---|---|
| £ | | |
| 1,833 | By Subscriptions | 1,980 7 0 |
| 53 | ,, Special Donation from the L.C.C. | — — — |
| 20 | ,, Subscriptions Outstanding (Estimated) | 20 0 0 |
| 62 | ,, Interest on War Stock and Defence Bonds | 71 3 11 |
| 3 | ,, Bank Interest | 2 6 3 |
| 9 | ,, Sundries, Subscriptions to Transactions, etc. | 6 12 8 |
| £1,980 | | £2,080 9 10 |

## BALANCE SHEET, 31st DECEMBER, 1941.

| 1940 | LIABILITIES. | £ s. d. | £ s. d. |
|---|---|---|---|
| £ | | | |
| 72 | Creditors | | 100 13 8 |
| | Subscriptions paid in advance | | 43 1 0 |
| | Capital Account:— | | |
| 2,139 | Balance per last Account | 2,422 4 7 | |
| | *Add* Excess of Income over | | |
| 283 | Expenditure for the year | 120 2 4 | |
| | | | 2,542 6 11 |
| £2,494 | | | £2,686 1 7 |

| 1940 | ASSETS. | £ s. d. |
|---|---|---|
| £ | | |
| 396 | Cash at Bank | 345 4 3 |
| 10 | Cash in hand | 11 2 4 |
| 1,560 | £1,500 3½ per cent. Registered War Stock at cost *(Value on Dec. 31st, 1941, £1,572)* | 1,559 15 0 |
| 500 | £750 National Defence Bonds at cost | 750 0 0 |
| 20 | Subscriptions Outstanding | 20 0 0 |
| 8 | Sundry Debtors on Sales Transactions | — — — |
| £2,494 | | £2,686 1 7 |

## LIBRARY FUND ACCOUNT, 31st DECEMBER, 1941.

| | £ s. d. |
|---|---|
| Balance at the beginning of the year | 21 14 6 |
| | £21 14 6 |

| | £ s. d. |
|---|---|
| Balance:— | |
| Cash at Bank | 21 14 6 |
| | £21 14 6 |

## LEON GASTER MEMORIAL FUND ACCOUNT, 31st DECEMBER, 1941.

| | £ s. d. | | £ s. d. | £ s. d. |
|---|---|---|---|---|
| Fund at the beginning of the year ... ... ... | 243 2 4 | Expended during the year:— | | |
| War Stock Interest ... ... ... ... ... ... | 8 1 0 | Premium for 1940/41 ... ... ... | | 10 10 0 |
| | | Balance:— | | |
| | | Cash at Bank ... ... ... ... | 4 0 2 | |
| | | Invested in £230 3½ per cent. Registered War Stock at cost ... ... | 236 13 2 | |
| | | *(Value on Dec. 31st, 1941, £241)* | | 240 13 4 |
| | £251 3 4 | | | £251 3 4 |

## NATIONAL ILLUMINATION COMMITTEE FUND, 31st DECEMBER, 1941.

| | £ s. d. | | £ s. d. |
|---|---|---|---|
| Fund at the beginning of the year ... ... ... ... | 308 2 9 | Balance:— | |
| War Stock Interest ... ... ... ... ... ... | 10 10 0 | £300 3½ per cent. Registered War Stock at cost ... *(Value on Dec. 31st, 1941, £314)* | 304 8 6 |
| | | Cash at Bank ... ... ... ... ... ... | 14 4 3 |
| | £318 12 9 | | £318 12 9 |

## INTERNATIONAL ILLUMINATION CONGRESS FUND (1931), 31st DECEMBER, 1941.

| | £ s. d. | | £ s. d. |
|---|---|---|---|
| Fund at the beginning of the year ... ... ... ... | 312 15 0 | Balance:— | |
| War Stock Interest ... ... ... ... ... ... | 10 10 0 | £300 3½ per cent. Registered War Stock at cost ... *(Value on Dec. 31st, 1941, £314)* | 304 8 6 |
| | | Cash at Bank ... ... ... ... ... ... | 18 16 6 |
| | £323 5 0 | | £323 5 0 |

We have examined the above accounts with books and vouchers, and certify same to be correct in accordance therewith, and that the Balance Sheet exhibits a true and correct view of the Society's affairs according to the information and explanation given to us.

Dated this 12th day of March, 1942.

ROBERT J. WARD & CO., *Chartered Accountants*,
Grosvenor House,
Park Lane, London, W.1.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members.*

CORPORATE MEMBERS:—

Davies, Lewis .....“Arosfa,” St. Teilo Street, Pontardulais, GLAM.
Donaldson, G. V....32, Montgomery Road, SHEFFIELD, 7.
Gregory, R. W. ...Pilgrim House, NEWCASTLE-ON-TYNE.
Harris, R. E. B.....Sloan Electrical Co., Ltd., 9, John Street, BRISTOL, 1.
Hobson, A. M. ....5, Cardoness Road, SHEFFIELD, 10.
Hughes, M. C. .....“Pentyla,” 95a, Stroud Road, GLOS.
Hutchison, A. J....Bradford Corporation Electricity Dept., 27, Bolton Road, Bradford, YORKS.
Jefferies, W. H. ...“Oldlands,” Frenchay, BRISTOL.
Jones, O. .....4, Lambpit Street, WREXHAM.
Langdon, L. E. .....Sicey Hotel, Sicey Avenue, SHEFFIELD, 5.
Martin, J. .....112, Spencefield Lane, LEICESTER.
Mayo, J. .....16, Elden Street, NEWCASTLE-ON-TYNE.
Miles, R. W.....70, Hinckley Road, LEICESTER.
Moodie, A. .....4, Haethorn Gardens, Low Fell, GATESHEAD, 9.
Murphy, W. J.....200, North Street, Bedminster, BRISTOL, 3.
Pilkington, J. .....14, Cyncoed Crescent, CARDIFF.
Randall, L. F.....16, Avery Hill Road, New Eltham, LONDON, S.E.9.
Reed, F. E. R.....“Springfield,” Memorial Road, Hanham, BRISTOL.
Rogers, C. N. .....“Rothwell House,” Station Lane, Thurnby, Nr. LEICESTER.
Rutherford, G. A...104, Sorley Street, SUNDERLAND.
Sloan, T. .....24, Oxford Street, NEWCASTLE-ON-TYNE.
Squire, J. W. .....157, Humberstone Road, LEICESTER.
Tarratt, F. A. H....28, Brandon Street, LEICESTER.
Wade, W. K. .....10, Highfield Terrace, HALIFAX.
Yates, F. A. .....10, Horsefair Street, LEICESTER.

ASSOCIATES:—

Bastin H. A.....16, Southville Terrace, Lyncombe Vale, BATH.
Clarke, A. E. .....270, Scraptoft Lane, Humberstone, LEICESTER.
Hardy, W. T.....11, Fernville Street, SUNDERLAND.
Hemstock, H. .....“Parkholme,” Hallatrow Road, Paulton, Nr. BRISTOL.
Hunt, Fred .....12, Greystones Crescent, Ecclesall, SHEFFIELD, 11.
May, J. F. .....32, Avoca Close, Wicklow Drive, LEICESTER.

* In accordance with the present procedure the names of applicants for membership are published in THE TRANSACTIONS as soon as such applications have received the approval of the Council and the subscription for the current year has been duly paid.

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# ADVANCE PLANNING IN LIGHTING RECONSTRUCTION

By HOWARD ROBERTSON, F.R.I.B.A.

*(Summary of an Address delivered on Tuesday, March 10, 1942.)*

The planning and architectural aspects of reconstruction are but elements in the pattern of general reconstruction, which in turn must be based on a social, political, and industrial policy. To take a concrete example:—There are some who hold that Great Britain will not, after the war, be in a position to rank as a great mass-producing industrial nation, capturing markets by the supply of cheap, efficient utility products. That, on the contrary, our highest asset, our greatest commercial tradition, derive from *quality* as opposed to quantity. That England in the future should be the place where people go to procure the best things of their kind.

Suppose such a policy was implemented. We would then logically attempt to bring into our planning and building those same standards of quality which we would be aiming at in industry. We would say, with truth, that what we have been doing for the past fifty years or more is not good enough. That we have little by little sacrificed everything to expediency. That we have always been too willing to spoil town and countryside by mess, untidiness, and slipshod planning and construction provided that it brought an immediate return and showed considerable saving over doing the same thing in a much better alternative way.

The conception of post-war planning and architecture will have to be examined in the light of general policy. We might say, There will be no money to spare, an enormous amount to rebuild, and to build afresh. It must all be done very quickly. Therefore, we must work on simple, clear-cut lines, and be practical, which may well mean that aesthetics—in their aspect of service to the community—have a take a secondary place. As regards buildings, we can assume that heights are controlled, standardised economic spacings for spans will be available, fenestration is governed by daylight illumination graphs, and standardised elements can do the rest, especially if certain ranges of materials are specified for certain streets. In housing, the system will be the same, or more so, because housing can be pared down to a very low point and still provide adequate shelter.

If something like this is envisaged in reconstruction it is pretty safe to guess that such questions as illumination will be treated in the same spirit. Provided that you can get light at night as well as by day, the minimum necessary that anyone can ask for will have been provided.

But if that is going to be the national policy, we can say good-bye to the finer conception of planning and building which regards all technical and scientific progress as profoundly influencing design, and as calling for far more design ability than ever before.

Architecture is not merely designing and putting up strong economic workable buildings. It embraces the welding into the structure of all the complex services required to-day, and doing it in such a way that all these services are combined and focused to make a resultant building not only useful but functional in the sense of satisfying the higher demands of the spirit. If man is merely an animal, give him a kennel, if he is anything like *homo sapiens*, let us work along different lines.

Illumination provides a capital instance of showing the difference between building and architecture. Suppose you put up a factory in peace-time, building it in the quickest and cheapest way, perhaps with North-lights, and then call in the illuminating engineer to string his lights wherever the equipment and heating engineers have left him some room. Will you get an efficient factory? You won't. Compare such a building with some of the latest American factories where lighting—whether fluorescent or wire filament—is admirably built into the structure, not interfering with daylight or any other requirements. In which factory will the work be more efficient? Which is just construction and which architecture?

Take again a shop. For example the new Tiffany Shop in New York, which is admirably illuminated both generally and in the showcase detail by lighting practically invisible. That lighting is all built-in. It could never have been achieved if it were not that the whole design of this showroom is built-up round the lighting.

I am not quoting these examples in order to go into detail. What I am trying to stress is that illumination is part of architectural design, and in that I include the design of streets and cities.

Furthermore, I believe that illumination should enter into all reconstruction conceptions. That standards should be set and insisted upon, and that there should be legislation to ensure control of signs, standard illuminated street numbers, and the lighting of public streets and open spaces.

The whole field has been admirably covered by Mr. R. O. Ackerley in his paper read before the Illuminating Engineering Society in May, 1941, entitled "Lighting and Reconstruction." Everyone interested should read that paper. It has obviously been constructed with great care, and after consideration of suggestions made to the lecturer by many qualified people. In it Mr. Ackerley points out that we are on the verge of great progress and possibly fundamental changes in sources of illumination.

What is wanted now is to go a step further and implement that collaboration between the architect

and the illuminating engineer which, as Mr. Ackerley said, provides the only hope of furthering the common cause.

The difficulties are very great. Few qualified individuals have the time or the means to devote to this subject. Committee work is not rendered easier by the fact that innumerable architects cannot earn a bare living these days. They have to turn to something else; they cannot live on air and on the innumerable offers of unpaid work which is about all they get.

In my opinion, the Ministry of Works and Planning ought to appoint a Director of Illumination in the same way as it has Directors of Bricks, of Standardisation, etc., and it ought to appoint a small paid panel of qualified men from the illuminating and architectural professions to make a proper study and report. Only that way will it get results. The Ministry cannot do the work itself, nor is there anything to prove that the Ministry unaided would have the right outlook on reconstruction. It may confuse the necessity for rapid temporary building in the immediate post-war period with the long-term policy of setting far better standards for the future. It will require great courage on the part of the Minister to convince the Government that to do things badly, and cheaply (in the derogatory sense), is to breed endless trouble in the future. One of our great defects is the inclination to patch, and make do, and consider expense first and foremost, without profiting by that bitter experience which shows time and again that we pay a far higher price in the end.

Parsimony and lack of imagination at the outset go hand in hand in too much of our national business. Illuminating engineering is one of the professions which is going to suffer most from just such policies. So is architecture. Perhaps joint representation in right Government quarters may achieve results. This meeting will, I hope, express its opinion and give guidance. I do not think we are here to discuss details of technics, or claims of rival systems, but to table our views on the importance or otherwise of considering illumination—and it will be almost the first time we have done it—as part and parcel of a programme of construction.

[Following his expression of opinion that the Ministry of Works and Planning ought to appoint a Director of Illumination, and should have a small paid panel of qualified men from the illuminating and architectural professions to make a proper study and report, Mr. Howard Robertson said that since he had prepared his remarks he had seen in the technical Press a neat chart of a set-up which the Ministry had in mind in connection with reconstruction. There were to be six small panels, one to deal with illumination; the convener was the D.S.I.R. It looked as though something were happening, for "illumination" was actually in print on a Government programme! But he did not think that the proposal went far enough, because he felt that the professions could not get into a committee of the kind envisaged in sufficient strength and with sufficient force to ensure that it would serve completely the rôle he had in mind.]

## DISCUSSION

Mr. GREY WORNUM commented that the remarks of Mr. Howard Robertson and the very interesting paper by Mr. Ackerley in 1941 hung together to the extent that they brought the architect very much into the picture with regard to scheming for lighting. He was, however, a little critical of some of Mr. Ackerley's remarks, which seemed to imply that it was the task of the architect merely to utilise and assign places to lighting fittings in buildings, without being concerned in their design. During the past twenty years he (Mr. Wornum) had found it needful to undertake much detail of illuminating engineering work, partly because illuminating engineers did not study sufficiently the make-up of the materials of lighting equipment, such as glass, metal and plastics.

In spite of all recent developments, no real substitute for natural lighting had been obtained, though the world was waiting most urgently for such a substitute. He recalled that when he visited California in the summer of 1939 he observed that in a large office building all the blinds were drawn, excluding the bright sunshine in the streets. The whole staff was working by artificial light, because the direct sunlight on a desk was intolerable and reflected light from walls apparently insufficient.

Although he had found neither in this country nor in America any really adequate substitute for daylight, he nevertheless believed that for general purposes artificial lighting in this country was probably better than in any other part of the world. He had been led to expect very much brighter lighting in America than here. Yet in public places in New York and elsewhere the illumination proved to be hardly sufficient to enable a newspaper to be read. He recalled instances where the light, of a yellow hue, gave less than 2 ft.c. On the other hand, in the offices of the General Electric Company and some of the department stores values of 40 ft.c. or more were quoted, but only 20 ft.c. found to exist.

As an instance of design to meet special requirements he mentioned the lighting of the S.S. Queen Elizabeth, where the initial illumination was 10 ft.c. and the conditions probably years ahead of other installations, for example, in regard to the wiring, which had to be carried in grooves and to be accessible at a moment's notice. The use of a new form of glass, of which he had learned in San Francisco and traced by way of Leipsic to Czechoslovakia, and finally to Paris, had enabled him to secure an illumination that cut yellow completely out of the spectrum, produced most becoming effects on people, and no eyestrain.

Glass would be of great importance in the future design of lighting fittings. In this connection he referred to the polarised "anti-glare" glass being developed in America. The possibilities for constructing fittings in light and strong metal alloys and of plastics should be examined—by illuminating engineers as well as by architects. Illuminating engineers had done splendidly in the development of standardised fittings for everyday use, but when an architect had to deal with the lighting of an interior of any importance he had to start from the beginning.

If there were to be surface wiring on the steel linings, plywood, etc., in the post-war houses, he said, let us get away from the circular tubular form, which was very bad; especially where it crossed a ceiling and where that ceiling had to be relined with paper. Incidentally, the metal conduit was a conductor of sound. It was very likely that the plastics industry, with some encouragement, could evolve extruded flat sections which would be very neat for surface wiring. If illuminating engineers would maintain open and enquiring minds in regard to developments in other industries, then by pooling resources we should all travel quite a long way towards the ideal.

Mr. J. MARKHAM (Ministry of Works and Buildings) appreciated that architects and illuminating engineers had considerable difficulty in discussing post-war needs, because nobody knew what the conditions would be. But if architects would consider what they would like to do and the conditions in which they would like to work, and would put forward ideal solutions for their various problems, they would at least provide ideals at which to aim. It would

be helpful to try to shape the conditions which would permit of the realisation of the ideal solutions of those problems. There was something to be said for that method of procedure; it was adopted in architectural schools, though in that case there was no danger of the students having to carry out their designs in practice!

Commenting on the probability that strip lighting fittings were likely to be used quite a lot after the war, a probability which was strengthened by the fact that they could be used economically, Mr. Markham said that that development would make a very big difference in the design of lighting fittings and in the disposition of the light sources, and that would, in turn, reflect on the architectural treatment of the rooms. The problem must be approached from the point of view of designing the rooms in order to make the best use of the lighting fittings available.

Finally he remarked, amid laughter, that if he heard that a Director of Lighting was to be appointed in the Ministry of Works and Planning he would use his utmost endeavours to secure the appointment of Mr. Howard Robertson, because if he approached the problem with the becoming humility with which he had approached it in the discussion, then certainly he would not do any harm—which would make it possible for other people to do some good!

Mr. R. O. ACKERLEY said that the problem with regard to the future was very complex. It was not so much a question of what they wanted to do, because, although they had not set it down definitely, they all knew fairly well what they wanted to do; the problem was rather to get it over. The Illuminating Engineering Society was trying to clarify the minds of the lighting profession and to formulate ideas as to what its members would like to do, through the Reconstruction Committee and its various sub-committees. He hoped and believed that the architects were also thinking about lighting, because they and the lighting engineers must get together if they were to deal with the problem satisfactorily; they must pool their ideas and make out a plan concerning the position of lighting in architecture. The architects, as the leaders, should put over the lighting story, the illuminating engineers providing them with the ammunition. If the illuminating engineers could fire a few shots independently they would do so; but much would depend upon the architects making use of the ammunition provided for their use. Having crystallised their ideas, they could go straight ahead as soon as the opportunity was presented.

He was sorry that his paper of 1941 had given the impression that in his view the architects were concerned merely to find suitable places for the lighting fittings. His view was that the function of the illuminating engineer was to give technical service to the architect; it was for the architect to say what he wanted, and for the illuminating engineer to provide it. Having clarified their respective functions, they should be able to do very much more good than they had been able to do in the past. There seemed to have been a tendency for many architects to think that the illuminating engineer was trying to teach them their business. The illuminating engineer knew that it was not his function to say what lighting should ultimately be achieved; it was his function to help to achieve what was required. Mr. Ackerley accepted the criticism that illuminating engineers had not done all that they should have done to make use to the best advantage in the lighting field of the various new raw materials available.

It was interesting to hear from Mr. Grey Wornum that, in the decorative lighting field—in hotels, restaurants, and so on—the lighting intensities were not high in America, and that the Americans were not ahead of this country in that field. One had often heard that illumination values were much higher in America than here. He believed, however, that in modern American factories, shops, and offices, etc., the illumination values were higher.

Mr. RALPH TUBBS, A.R.I.B.A., recalling a remark by Mr. Ackerley, in his paper on Reconstruction, that the lighting engineer could give his best service to the community only through and with the help of the architect, said it was equally true that the architect could give his best service to the community only through and with the help of the community itself. Therefore, we were all dependent on the policy of the community.

Those present at the meeting were scientists, technicians, and artists, and he supposed that most of them had in the past found so much interest in their work that they had tried to keep themselves free from political issues; certainly he had tried to do so. But after working hard on analysing the many problems presented by the reconstruction of our devastated cities, and also the problem of those cities which had not been bombed but were equally in need of replanning, he had been impressed by the amount of knowledge which existed among technicians and specialists and by the simply appalling lack of use made of that knowledge by those in control.

When one discovered how officials were approaching the problems of replanning our cities, one shrank back in the fear that again it might be a case of "too little, and too late." In those circumstances he felt that it would be irrelevant to discuss details; it was completely unrealistic to work in watertight compartments on details, when the main issues for which they were striving were not accepted.

Appealing, therefore, that we should concentrate on the main issues, and especially that of reducing the time-lag between research and application, Mr. Tubbs enquired into the history of that time-lag. In the first place, he said, it must be borne in mind that, whether we liked it or not, it had become an accepted principle in England that public demand preceded legislation. The law was not meant to lead. That in itself implied a considerable time-lag, for the desire for progress in any sphere had first to be aroused in the forty-eight million inhabitants of this island before anything could be done about it. There one found the key to the trouble; supposing if it were not the national policy to stimulate the desire for progress in the mass of the people, their apathy could be exploited so that they received only the minimum for which they asked.

In the nineteenth century the great figures were the pioneers of scientific achievement. Those men, starting from the mass of the people, set out ahead on the path of knowledge; they were to show the direction in which man should go if he sought better conditions. But nowadays the finest scientists and thinkers were so far ahead of what was actually being carried out in this country that they had progressed out of sight of the people. Men did not know where to go because their true leaders had gone over the hill-top.

Do not let us think, he continued, that we were being most progressive by hurrying onward over the hill-top, too. The greatest service that a man could render in the twentieth century was to come back from the hill-top from which he had last seen the leaders and join the people, to show them the way the true leaders had gone. It was regrettable that somewhere in the midst of the people, and, indeed, somewhere near their rear, one would find the official and political leaders, wondering with the rest of the people which way to go.

It had been suggested by Mr. Ackerley, in his 1941 paper, that the Illuminating Engineering Society should set up a committee to study the problem of illumination from the political angle, in order to decide how best the services of the Society could be placed at the disposal of the community and to examine the ways and means of getting general adoption of good lighting principles. Such a committee, if it had been set up, had tremendously important work to do. When the value of expert knowledge was appreciated, detailed research was enormously valuable. Before that day we had the great task before us of getting the principles of a dynamic and constructive policy accepted—of showing the way over the hill-top. Having done that, many of our own individual problems of lighting or architecture would solve themselves. The time-lag between research and application would at once be reduced. Only when the framework of the planning policy was right (and that would be right only when the framework of society was right) could we legitimately work on the details. No one realised more bitterly than the architect how hopeless it was to work on the details when the main plan was wrong.

Let us, therefore, work with energy to show how fine our cities might be, what good architecture really was, how workplaces and homes could be made much more pleasant with proper lighting, how streets could be made safe with correct

illumination; only when the people knew what they were missing could they possibly demand what was right. Only when they demanded what was right would they get a sound policy of reconstruction. And when that policy took shape in building, perhaps man would remember that, as Mr. Howard Robertson had pointed out, he was once called *homo sapiens*.

Mr. WILLIAM ALLEN, emphasising the importance of elucidating principles in applied science and of avoiding too much detail, said he was disturbed very often by the attitude that the architect adopted towards the problems with which he was confronted, among those problems being that of illumination. It was a commonly held view among architects that their position was tending to become that of rather superior organisers calling upon and co-ordinating the services of a great many specialists. A little consideration of that view, however, would show that the position would soon become one of practical absurdity. It would be unwise to think that an architect had to bring in a specialist in every field of his work. In the development of applied science we were suffering from an over-emphasis of detail and a relatively poor development of the principles; we tended to see none of the wood for the trees—and that was a situation which baffled so many laymen approaching a technical subject. An enormous amount of detail was overburdening. For example, when he had first become connected with research work on sound transmission it had appeared still to be a very confused problem; but within two or three years it had become possible to set it out in the form of simple technical and design principles which enabled architects to arrive at their own solutions. He and his colleagues at the Building Research Station tended to the view that the elucidation of principles for the architect was becoming rapidly one of the most important problems in applied science. The architect, given a knowledge of the simple principles of each sphere in which he had to exercise some control, would be able to dispense effectively with the small design problems for which specialists were not justified. When he was faced with problems in connection with which the employment of a specialist was legitimate, he would be able to provide in his sketch plans and drawings and his initial conception of a building a more satisfactory background for the operation of the principles. Though this did not mean, of course, that he should delay the time for consultation.

Mr. Allen suggested that the best basis for better co-operation between the illuminating engineer and the architect would be a simple, clear statement of the technical and design principles involved, and he felt that in the undoubted labour of simplification, the illuminating engineer himself might find benefit. He did not see that co-operation was practical on any other basis.

Mr. D. W. DURRANT, emphasising Mr. Allen's remarks, urged that some action should be taken at once, for otherwise we should soon be swallowed up in jerry building, just as we were after the last war. With regard to co-operation between architects and illuminating engineers, he said the main point was that they must make friends of each other. Life was too short to enable one to know everything about everything, and therefore the services of specialists were necessary; but there must be co-operation, so that they did not reach a situation in which all were sitting like tin gods on unapproachable thrones. The more the illuminating engineer could appreciate the thoughts and outlook of the architect, the more would the "feeling" of our buildings be interpreted for the benefit of the community.

Stressing the importance of the regular maintenance of fittings and of making proper provision for it, Mr. Durrant said this had been found profitable in the case of the tungsten lamp; how much more profitable was it in the case of the fluorescent tube, which had much more surface area on which dust could collect? Human nature being what it was, however, unless the means of cleaning were made easy and obvious, the cleaning would not be done regularly; it was too much to expect anyone to poke an arm through a small aperture to clean a fitting whilst being able to see little more than if blindfolded.

In the domestic sphere the illuminating engineer had a tremendous opportunity and responsibility. The standard of lighting in the majority of homes to-day could very well be described as atrocious. This is in some measure due to economic reasons, but the lack of education and appreciation of the benefits of good lighting must be held largely responsible. In the past it had been possible to plan houses with large numbers of rooms, each room for a particular purpose, decorated and lit in a manner suitable for that purpose. The trend seemed to be to consider modern living in but three main divisions—the kitchen, the bedrooms and the living space—and it was very difficult to determine any standard for what was required. In the living space, for instance, sometimes one wished to sit by the fire and smoke and dream and listen to the radio, and in those circumstances perhaps some of the "glamour" lighting to which Mr. Grey Wornum had referred would be desirable; at any rate, the light should be soft and intimate. But in that same living space at other times one wished to work, read, write, or conduct hobbies; so that it should be possible to increase the lighting intensity to something approaching the 40 ft.-c. mentioned in connection with the G.E.C. offices in America. At all times the installations, to be satisfying aesthetically, must look complete. Nothing looked worse than to see one of the old type of multi-lamp chandeliers with half the lamps extinguished, as though they were burned out.

Finally, Mr. Durrant suggested it might be useful for the meeting to pass a concrete resolution that illuminating engineers and architects should use every means of association to appreciate each other's outlook, which in both cases should be part of a common reasoned order.

Mr. P. V. BURNETT said that the tendency to regard natural and artificial illumination as two quite different problems, with different solutions, still persisted, and he suggested it was time that the illuminating engineers decided upon their ambition. If artificial illumination were a substitute for sunlight or daylight, did not that mean that the ambition must be to provide artificial light which was indistinguishable from natural illumination? As an architect he was faced with the intolerable proposition of having to design interiors for two quite different lighting conditions; he had to design windows for natural illumination, and then had to design all over again for a totally different lighting condition at night. In his view, that was wrong. If we were aiming at a substitute for natural illumination, let us get rid of the "fitting complex" and try to provide artificial illumination from the same openings as were used for natural illumination, and of similar intensities and other qualities.

Up to the moment, daylight research seemed to have been conducted backwards. A tremendous amount of research had been made by the Building Research Station, the National Physical Laboratory and private research workers on methods of calculating the amount of light which would pass through fixed window openings. But from the architect's point of view that seemed to be the wrong procedure; the problem was to design a window through which a fixed amount of daylight could pass.

Finally, he urged that scientific reports should be presented in non-technical language, and complained that those who prepared such reports were inclined to take too much for granted. They often assumed that their readers knew all that had gone before; the result was that many readers, not knowing what had gone before, would read the first two paragraphs and then close down. Thus, some research results were not taken up at all, whereas other results were taken up because they were presented properly. Perhaps the illuminating engineers required poster writers and advertising agents on their committees, to present their results in ordinary common-or-garden English!

The PRESIDENT, interposing, recalled that a few years ago the manufacturers of lighting appliances had employed an architect and had devoted a considerable amount of study to the understanding of architectural "jargon" and to the interpretation of the architect's requirements. It was of obvious importance that both should come to appreciate each other's point of view and to understand his method of expression.

Mr. W. WATSON stressed the importance of developing the

public taste in regard to lighting. One of the most difficult obstacles which the architect had to overcome was the taste of the average citizen. The public, however, could not be compelled, but could only be guided in the right direction. If the Illuminating Engineering Society could give that guidance, more could be achieved than by the efforts of architects alone.

Mr. R. F. TAYLOR, speaking as one who was neither an architect nor an illuminating engineer, emphasised Mr. Burnett's remarks with regard to daylight, and said that any one design of window would not necessarily afford the best illumination for all rooms. He urged that research was necessary in order to establish the first principles. When one heard that in offices in San Francisco the blinds were pulled over the windows and artificial lighting resorted to on sunny days, one felt that there was something wrong with the design of the windows.

Mr. BRIAN PEAKE, who described himself as "an architect, and proud of it," agreed that architects should have knowledge of the basic principles of illumination, and said that they could best acquire that knowledge when they were young. Therefore if the Illuminating Engineering Society could find a means of giving the information to architectural students, it would do a great deal of good. In that connection he recalled that the Electric Lamp Manufacturers' Association had in the past arranged some very interesting illustrated lectures, and he wondered whether the Society could do something on the same lines, dealing not only with artificial lighting, but also with design for natural lighting. Present design of windows was not functional, and needed great improvement.

Discussing windowless versus windowed buildings, he said that, inasmuch as many people had now to work in blackout conditions during the day, the opportunity might be taken to determine the effect of such conditions upon health. When people were working in artificial light all day, what was the effect upon their eyes, what was the effect of the loss of certain health-giving rays, and so on? On the psychological side, how did the workers react to conditions in which they were unable to look out of the windows during the day, and did they miss the constant variations of intensity of daylight? Again, was there any difference between the heat produced by artificial light and by daylight? He wondered whether the Industrial Welfare Society could conduct inquiries in that direction.

Mr. H. E. BECKETT (Ministry of Home Security) suggested that in the past the lighting of interiors by daylight had rather suffered from the fact that no one had been directly concerned with selling daylight. It seemed to him that one of the best ways of selling artificial light was first to improve the day lighting of interiors; for, where the day lighting in buildings was improved, the demand for better artificial lighting followed. When the lamp manufacturers realised that the development of the science of day lighting might progress more rapidly.

Mr. PERCY GOOD (British Standards Institution) warned that after the war it would be necessary to meet and overcome the arguments of those who would contend that we could not afford to do the things that ought to be done, and said that those arguments could best be met by putting forward the financial aspect in its true perspective. People had from time to time referred to the colossal amount of building damage resulting from enemy action in this country; but when analysed it worked out to less than half a year's normal house building programme. If it were insisted that buildings, including factories, should have a more dignified appearance, and if it were suggested that the work that it was desirable to do on any one factory would cost an additional £20,000, £30,000, or £50,000, one might be perturbed about that extra cost. But if one considered that extra cost as a percentage addition to the cost of the product of the factory per annum, it would probably work out to the third place of decimals in pence. Again, a façade costing perhaps £100,000 could be suitably illuminated and endowed in perpetuity for an additional 5 per cent. on the cost. He believed that in connection with post-war planning we shall be harassed by those who complained of costs; but if we could in advance present the matter in its true perspective we shall have some chance of success.

Mr. L. G. APPLEBEE emphasised Mr. Allen's reference to the importance of co-operation between the architect and the specialists in the earliest stages of the design of public halls, such as school and church halls, and town halls, which had to cater for all kinds of public enterprise and entertainment —political meetings, badminton, dances, theatrical performances, orchestral concerts, etc. It was surprising, he said, how many very fine public buildings, school and church halls, etc., suffered at the stage end, and how much of the expense of unsatisfactory jobs could be avoided if there had been conferences between the architects and the specialists in the early stages of the design. In considering the lighting, the architect should confer not only with the illuminating engineer, but also with those concerned with the stage set-up, because the problem of the lighting of the stage was linked up with the amount of room required for manipulating scenery, and so on. In the stage lighting of public halls the Americans were very much ahead of us.

The same argument applied to the use of neon and other signs and illuminated exterior publicity on buildings. Too often signs were affixed to buildings a year or two after construction, and were not considered in relation to the design of the buildings; it was desirable that, when a building was designed, the neon signs should be considered not only as part of the aesthetic whole but also to overcome difficulties in respect of local authorities' requirements.

Mr. HOWARD ROBERTSON, commenting on the discussion, said it indicated that there was need for a forum of some kind; there were so many aspects of the problem of advance planning in lighting reconstruction that he did not believe a Government Department could cope with it alone. He did not think machinery had been evolved for placing the various views into coherent form in order to aid reconstruction, but he hoped that something would be done to that end, in the interests of the whole community.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the List of Members:—

CORPORATE MEMBERS:—

Andrews, E. W. ...Kensington Buildings, Stockton Road, SUNDERLAND.
Brown, W. R. F. ...158a, Edmund Street, BIRMINGHAM.
Cornick, A. L. ....." Wayside," Llantarnam, MON.
France, W. .....2, Carfield Place, SHEFFIELD, 8.
French, W. H. .....53, Highway Road, LEICESTER.
French, W. A. A....17, Romway Avenue, LEICESTER.
Gray, T. C. .....Gray Bros., Newcastle, Ltd., 149, Pilgrim Street, NEWCASTLE-ON-TYNE.
Ham, W. S. .....18, Imperial Road, BRISTOL, 4.
Kirkland, R. .....5, Blagdon Street, Blyth, NORTHUMBERLAND.
Lowrey, A. S. .....146, Moorside, North Fenham, NEWCASTLE-ON-TYNE.
McQueen, A. H. ...Tanhouse Farm, Berkeley, GLOS.
Oldham, J. K. ...26, North Park-grove, LEEDS 8.
Orrin, F. J. .....Treforest Trading Estate, Taffs Wells, GLAM.
Pernet, E. G. .....12, Kingsholm Square, GLOUCESTER.
Shackelton, H. A...30, High House Road, Bolton, BRADFORD.
Smith, F. A. .....Wyvern House, 65, London Road, LEICESTER.
Spalton, F. .....42, Longland Drive, Totteridge, HERTS.
Verity, H. .....16, Bideford-avenue, LEEDS 8.
Watson, G. W. ...The General Electric Co., Ltd., 4, Cheap Street, BATH.
Weston, H. J. .....15, Byron Street, Redfield, BRISTOL, 5.
Wilson, L. .....65, Crawshaw Grove, SHEFFIELD, 8.
Woolfenden, D. G..H.M. Inspector of Factories, 21, Rutland-street, LEICESTER.

# NOTES ON RECENT MEETINGS AND EVENTS

### Annual General Meeting.

The Annual General Meeting of the Illuminating Engineering Society was held in the Lecture Theatre of the Institution of Mechanical Engineers (Storey's Gate, Westminster, S.W.1) on Tuesday, May 12, 1942.

THE HONORARY SECRETARY having read the notice convening the meeting, the minutes of the last Annual General Meeting, which had been published, were taken as read, and confirmed.

THE PRESIDENT then formally presented the Report of the Council and Accounts for the past year, alluding to several salient features, such as the encouraging growth of membership, the further development of Centres and Groups, and the record of meetings held. It was recalled that, no other nominations having been received, the officers and members of the Council for the forthcoming session would be as specified in the report. The President alluded with appreciation to the services of the retiring Honorary Treasurer, Mr. E. W. Murray, during his period of three years in office. It was also mentioned that the Council had in view arranging in future for the report of the Council to cover the same period as the accounts of the Society, namely, the previous year (January 1—December 31).

The following resolution was then proposed by DR. E. C. WALTON (North Midland Centre) and seconded by MR. S. G. TURNER (South Wales Group), and on being put to the vote was declared carried unanimously:—

> "That the Report of the Council for the Session 1941-1942 and the Accounts of the Illuminating Engineering Society for the period from January 1, 1941, to December 31, 1941, be hereby adopted, and that a vote of thanks be extended to the President, Council, and officers for their efforts on behalf of the Society during the past Session."

The following resolution was then proposed by MR. C. I. WINSTONE and seconded by MR. W. R. STEEVENS, and on being put to the meeting was also declared carried unanimously:—

> "That this meeting records appreciation of the services of Messrs. Robert J. Ward and Co. as auditors of the Society, and approves of their re-election for the next Session."

This terminated the business, following which an ordinary sessional meeting was held.

### Sessional Meetings in London.

A sessional meeting was held in the Lecture Theatre of the E.L.M.A. Lighting Service Bureau (2, Savoy Hill, London, W.C.2), on Tuesday, April 14, at 5 p.m. The chair was taken by the President (Mr. W. J. Jones).

After the minutes of the last meeting had been taken as read, the chairman called on Mr. J. N. Aldington to present his paper entitled "Fluorescent Light Sources and their Applications," which was illustrated by lantern slides and effective demonstrations. The discussion was opened by Mr. H. R. Ruff, and amongst other speakers the following took part: Dr. J. W. T. Walsh, Mr. R. O. Ackerley, Mr. G. W. Golds, Mr. Jones, Mr. J. P. Ryan, Mr. F. C. Raphael, Mr. Lawson, Mr. A. G. Ramsey, Mr. A. Cunnington, Mr. O. S. Evans, Mr. Barron, Mr. J. S. Dow, and Mr. C. H. Hughes.

After the author had briefly replied to the discussion votes of thanks to Mr. Aldington for his paper and to the E.L.M.A. Lighting Service Bureau for their hospitality terminated the proceedings.

The final sessional meeting was held immediately after the annual general meeting on May 12, 1942, in the Lecture Theatre of the Institution of Mechanical Engineers (London, S.W.1).

The minutes of the last meeting having been taken as read, the President called upon Mr. G. H. Wilson to deliver an address entitled "Street Lighting, Past, Present, and Future." The address referred mainly to the period 1928-1938, during which a number of outstanding events occurred. Amongst these Mr. Wilson mentioned the demonstrations in Sheffield in 1928, the introduction of sodium and mercury vapour lamps, and the appointment of the M.O.T. Committee in 1934. He also referred to researches on the effect of road surface brightness, visibility, and the "siting" of positions of posts. After a brief reference to war conditions, the lecturer referred to possibilities in the future, pointing out the abundance of technical resources and the need for constructive planning.

In the subsequent discussion Dr. C. C. Paterson, Mr. E. J. Stewart, Mr. P. Good, Mr. J. F. Colquhoun, Mr. Howard Long, Mr. A. H. Owen, Mr. A. R. McGibbon, Mr. A. Maxted, and Mr. J. M. Waldram took part. After Mr. G. H. Wilson had briefly replied, a cordial vote of thanks to him for his address terminated the proceedings.

### I.E.S. Fellowship.

The following applications for Fellowship have been accepted by the Council:—

| | |
|---|---|
| Allpress, H. S. | 32, Gade Avenue, Watford, HERTS. |
| Barlow, H. S. | Flat 2, 1, Carlisle Road, Hove, 3, SUSSEX. |
| Davidson, E. J. | 33, Herbert Avenue, Merrion, DUBLIN. |
| Golds, G. W. | 7, Chesterfield Road, West Ewell, SURREY. |
| Holdsworth, T. C. | 103, Cookridge Lane, Cookridge, LEEDS. |
| Hopkinson, R. G. | 40, St. Andrew's-avenue, Sudbury, MIDDLESEX. |
| Morton, C. A. | 12, Sunleigh-road, Alperton, Wembley, MIDDLESEX. |

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."*

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# FLUORESCENT LIGHT SOURCES AND THEIR APPLICATIONS

By J. N. ALDINGTON, B.Sc., A.I.C., F.Inst.P. *(Member)*

*(Paper read in Manchester on January 15th, 1942, and in London on April 14th, 1942.)*

During the last few years there has occurred both in America and in this country a remarkable expansion in the use of fluorescent substances as sources of light. A phenomenon which until a few years ago was of theoretical rather than of practical importance now forms the basis of a rapidly growing branch of the electric lamp industry.

Fluorescent substances of types long known but now made with greatly improved properties are being used in conjunction with mercury vapour lamps of various kinds. New fluorescent compounds have been developed specially suitable for excitation by the resonance radiation from the electrically excited mercury atom. Combinations of suitable powders have been achieved by which white light can be produced efficiently. Probably the most important of these developments are those sources in which the major proportion of the emitted light is produced by fluorescence as distinct from those in which fluorescence is used to modify the colour from an already efficient light emitter. Both classes, however, have distinctive features and will be considered separately in the following order:—

(1) Sources in which fluorescence is used to produce modulation of the colour of the primary light. Light Modulators.

(2) Sources in which the emitted light is produced almost entirely by fluorescence.

The principal sections of this paper will be devoted to reviewing the development of these two important categories of light sources, considering some details of 80-watt tubular fluorescent lamps and gear and their applications, while the concluding section will consist of a short review of some other possible lines of development.

## TYPES OF FLUORESCENT SOURCES

### Class 1: Light Modulators.

The primary source of light in this class of lamp is an electric discharge through a metallic vapour. The resulting radiation is either reflected from or transmitted by a coating or layer of fluorescent substance, the purpose of which is to modify the colour of the primary light in order to render it more suitable for illumination purposes. Proposals for the use of fluorescing materials in this way were made by P. Cooper-Hewitt early in this century in connection with the mercury vapour lamp bearing his name. One of the reasons for the lack of success at that time was the inefficiency of the fluorescent material available and its rapid deterioration when exposed to mercury vapour radiation. Cooper-Hewitt apparently carried out experiments with the organic dyestuff rhodamine which fluoresces red under the stimulus of radiation of shorter wavelength. Unless the dyestuff is disposed in a special manner in suitable media it slowly decomposes when exposed to bright light, and this phenomenon alone would perhaps account for the lack of success of this early work.

Proposals were made early in the last decade for the association of rhodamine coated reflectors with lamps of the high pressure mercury vapour type. These reflectors and panels were designed to be used in fittings of various kinds in association with the 400 watt mercury lamp type MA and by transforming a proportion of the incident radiation into orange-red light would have the effect of improving the colour rendering properties of the source. Some excellent results may be obtained in this way, but even specially prepared rhodamine dyed surfaces were not found to be sufficiently stable under high intensity irradiation. Various schemes of this kind did not find any extended practical field of use. One reason for this was probably the development of improved fluorescent substances which had excellent stability because unlike rhodamine and kindred materials they were inorganic. Zinc cadmium sulphide was one of the first of these substances to find practical use in the construction of fluorescent light sources. In the first instance experiments were carried out to incorporate in special fittings panels coated with the fluorescent material. Considerations such as the necessity for maintaining a clean powder surface as well as the need for properly regulating the powder disposition and density soon led to incorporation of the powder on the inner surface of the lamp bulb.

The mercury vapour discharge itself takes place in a tubular bulb constructed from either a special borosilicate glass or from quartz, and the concentration of mercury vapour ions corresponds with a vapour pressure in excess of 400 mm. Suitable fluorescent substances are coated on the inner surface of the outer bulb in which the discharge tube is mounted. They are of a type which strongly absorbs energy of wavelength between 3,000 A.U. and 4,000 A.U. In the design of lamps of this type account must be taken of the temperature characteristics of the powders employed, as in most cases an increase in the temperature of the fluorescent powder layer reduces the ability of the powder to transform ultraviolet radiation into light. In some cases also the colour of the fluorescence is modified at increased temperatures. These effects are shown in Fig. 1, where the relative efficiency of various powders is indicated over a range of temperature. From these curves it will be seen that to be effective the temperature of the fluorescent layer should be as low as can conveniently be achieved.

In the case of the well-known 400-watt fluorescent lamp, in order to keep the outer bulb size as small as possible compatible with the above considerations, an isothermal contour for the bulb wall was worked out corresponding with a powder temperature not exceeding 160°C. The luminescent material most generally used is a zinc cadmium sulphide, which

absorbs the blue and near ultra-violet radiation of the mercury and cadmium high pressure discharge and transforms it into orange-red radiation. Zinc cadmium sulphide exhibits both fluorescence and phosphorescence, i.e., it emits light simultaneously with the absorption of radiant energy and continues to emit it for a measurable time after cessation of the incident radiation. For this reason in the 400-watt fluorescent lamp there is a noticeable reduction in the flicker associated with electric discharge lamps when operated on alternating current supply mains, as the phosphorescent light helps to bridge the gap between the cyclic rise and fall of the primary light emission.

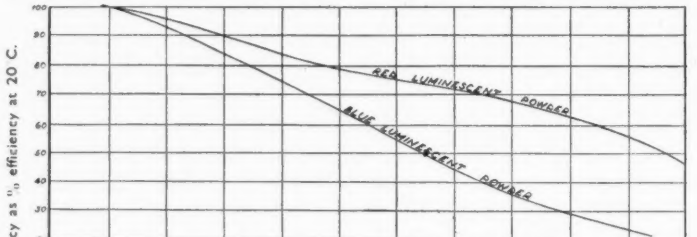


Fig. 1. Relative efficiency of blue and red fluorescent powders over a range of temperature.

A later development was the application of fluorescent powders to the 80- and 125-watt quartz high-pressure mercury lamps. The spectrum of these lamps is very suitable for colour modulation by fluorescence, as the high pressure at which the mercury vapour operates results in an improved distribution of energy in the visible spectrum. In the ultra-violet spectrum also the distribution of energy between 2,500 A.U. and 4,000 A.U. is favourable for the excitation of both blue and red luminescent materials, both of which can usefully complement the primary radiation from the discharge tube. (See Fig 2 (a).) For this purpose, as in the case of the 400-watt fluorescent lamp, the powders are coated on the inner surface of the bulb which encloses the discharge tube. The proportions of the blue and red

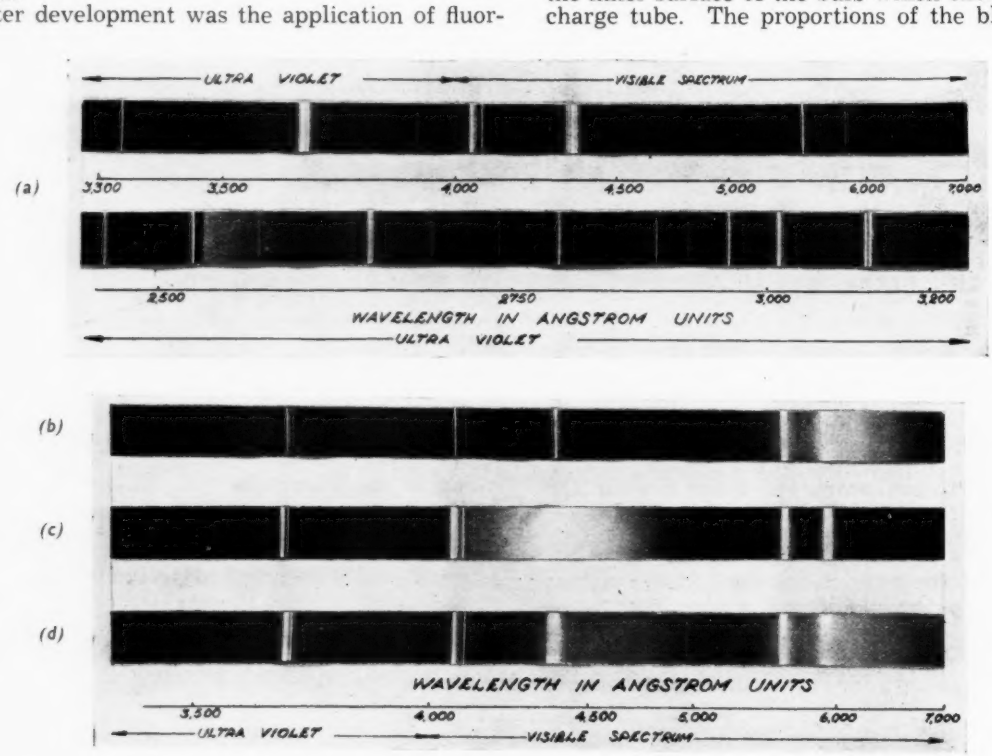


Fig. 2.

fluorescent powders are chosen to give the optimum colour modulation in those portions of the spectrum to which they contribute.

A spectrogram of the radiation from the quartz burner of a 125-watt high-pressure mercury lamp is given in Fig. 2 (a). It will be appreciated that the outer bulb in which this burner is mounted will be subjected to radiant energy emitted at a large number of wavelengths from about 2,000 A.U. in the ultra-violet region up to at least 8,000 A.U. in the infra-red. Some of the energy is absorbed by the fluorescent powder layer and re-emitted as light, while below about 2,800 A.U. practically all the remaining energy is absorbed by the glass bulb. The spectrograms in Fig. 2, marked (b), (c), and (d) show respectively the effect of red, blue, and a mixture of these sulphide powders when coated on the inner surface of the outer bulbs enclosing 125-watt quartz HPMV lamps. The blue powder is very effective in providing radiation in the region 4,200-4.800 A.U. while the fluorescence of the red powder is mainly above a wavelength of 5,700 A.U., i.e., in the orange and red region of the spectrum.

Bulbs of approximately spherical form are used, and the dimensions are chosen so that the temperature of the powder is sufficiently low to allow of the development of a high efficiency. The characteristics of these lamps are now well known, but for the sake of completeness they are given in Table I. below:—

**TABLE I.**

| Wattage | Bulb Diam. | Overall length | Cap. | Init. effy. | Av. effy. | 1,500 hrs. | % red approx. |
|---|---|---|---|---|---|---|---|
| 80 | 110 mm. | 178mm. | 3 pin Bayonet | 38 L/W. | 30 L/W. | 28 L/W. | 5% |
| 125 | 130 mm. | 233mm. | GES | 40 L/W. | 32 L/W. | 30 L/W. | 5% |

A word of explanation is perhaps necessary in regard to the figures given in the last column of the above table. The percentage red which is of the order of five is obtained by measuring the proportion of the total light emitted from the lamp which will pass through a Wratten No. 25 red filter. The implication of the statement is therefore that the distribution of radiant energy from these high-pressure fluorescent lamps is such that about 5 per cent. of the luminosity is due to energy which has a wavelength greater than about 6,000 A.U., the absorption curve of an average Wratten 25 filter being similar to that shown in Fig. 3. It will be realised that this index figure for percentage red gives nothing more than an indication that in the spectral region from 6,000 A.U. to 7,000 A.U. the various types of H.P. fluorescent lamp emit a proportion of light which lies between the corresponding values for the uncorrected mercury lamps on the one hand and daylight on the other, as shown in the following table:—

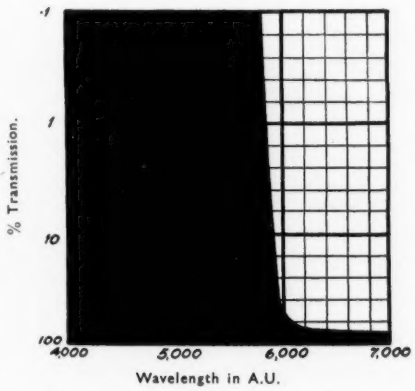


Fig. 3. Transmission of Wratten Filter 25.

*Illustration taken from "Wratten Light Filters" by kind permission of Messrs. Kodak, Ltd.*

**TABLE II.**

**Comparison of red content of light from corrected and uncorrected mercury vapour discharge lamps and that of daylight.**

| | Uncorrected | Corrected. |
|---|---|---|
| High-pressure mercury vapour in hard glass envelope | Approx. 1% | approx. 5% |
| High-pressure mercury vapour in quartz envelope | Approx. 2% | approx. 5% |
| Daylight | Approx. 15% | |

Methods for assessing the colour rendering properties of a light source must take account of the luminosity of the radiation which is being studied not in one limited region only but over the whole visible spectrum between the approximate limits of 4,000 A.U. and 7,000 A.U. An approximate method for doing this has been developed, and consists in measuring the relative luminosity of the radiation in eight bands covering the visible spectrum. Some experience is necessary to enable the results of such measurements to be interpreted. The results may for example be studied in the form of a series of measurements as in Table III below, or may be considered graphically as in Fig. 4. In each case a knowledge of the corresponding results for a light source of known character is useful as a basis of comparison. Further reference will be made to this method in connection with the assessment of the

**TABLE III.**

**Spectral Band Luminosity Data.**

| Wavelength Bands in Ångstrom Units. | 400-watt (Clear Bulb). | 400-watt (Isothermal) | 125-watt Pearl Quartz. | 125-watt Powder Quartz. |
|---|---|---|---|---|
| 4000—4200 | .002 | .002 | .005 | .002 |
| 4200—4400 | .64 | .30 | .50 | .32 |
| 4400—4600 | .044 | .07 | .11 | .15 |
| 4600—5100 | .68 | 1.7 | 1.5 | 1.7 |
| 5100—5600 | 54.0 | 46.2 | 49.8 | 44.2 |
| 5600—6100 | 44.3 | 48.7 | 47.8 | 50.0 |
| 6100—6600 | .4 | 3.0 | 1.3 | 3.6 |
| 6600—7200 | .13 | .19 | .17 | .25 |

colour of the latest types of fluorescent light sources which will now be considered.

**Class 2: Sources in which the emitted light is produced almost entirely by fluorescence.**

In the types of lamp just described only a limited region of the ultra-violet spectrum of mercury is utilised, namely, radiation occurring at wavelengths above about 3,000 A U. The spectrum of mercury is, however, particularly rich in short wavelength radiation and under low temperature conditions the dominant wavelength at which energy is radiated from the electrically excited mercury atom is 2,537 A.U. Energy of this short wavelength is a very powerful activator and is capable of exciting to fluorescence many of the substances which are normally used on the screens of cathode ray tubes.

The fact that many types of glass exhibited a certain amount of fluorescence when bombarded with either cathode rays or short wavelength ultra violet radiation had been known for many years. Certain constituents in the glass composition were found to influence this effect beneficially and (subsequent to about 1920) a number of special glasses were introduced which fluoresced quite strongly under the direct radiation from the low pressure mercury discharge. One of the first practical uses of this effect was the production of green high voltage sign tubes. A uranium glass which exhibited a bright yellow fluorescence was used for making up high voltage sign tubes of the mercury type, that is tubes which in clear glass would give a pale blue light. The combined effect of the blue mercury glow, and the yellow fluorescence of the uranium glass was a pleasing green. A later introduction was that of a whole series of special fluorescent glasses which were fabricated into two or in some cases three ply tubing. For example, the finished tubing would have its inner surface of special fluorescent glass and its outer surface of a more ordinary glass better able to resist thermal and mechanical shock and more resistant to weathering than the fluorescent layer. These developments enjoyed a certain popularity, but there were disadvantages when the tubing was used for the manufacture of coloured sign tubes of the high voltage type. The peak fluorescent effect was produced with quite low current densities, and unless very special precautions were observed in processing the tubing the fluorescence was often rather transient and hence the tube colour was not very stable. The next stage was reached when methods were worked out for the application of a layer of fluorescent powder to the inner surface of glass tubing, and the results obtained thereby stimulated the development of new powders more effectively excited by the dominant radiation from the low pressure mercury discharge.

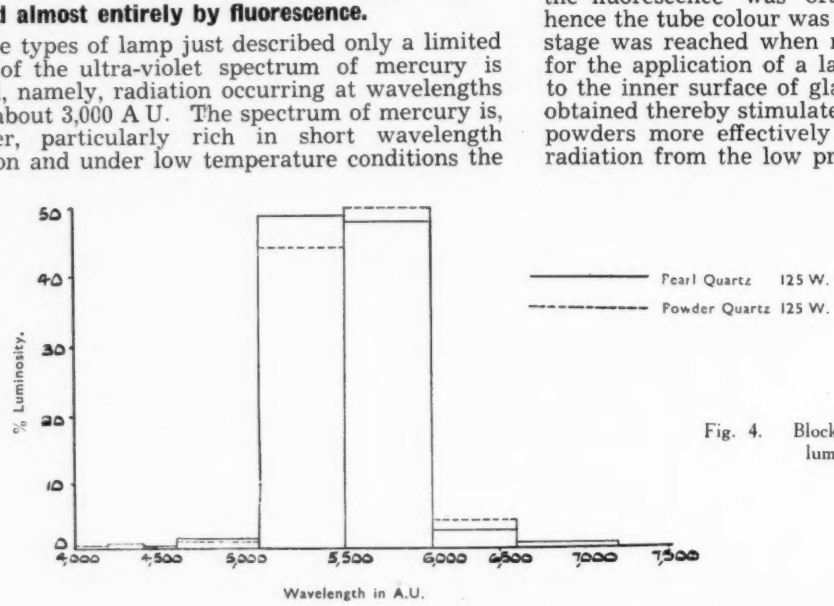


Fig. 4. Block diagram from spectral luminosity data.

Under the optimum condition of temperature, and therefore of mercury vapour pressure, more than 60 per cent. of the energy in the discharge is radiated at the resonance wavelength of 2,537 A.U. It was therefore evident that the most efficient types of fluorescent powders for operation on the inner surface of low pressure mercury discharge tubes would be those which are designed to absorb strongly radiation of 2,537 A.U. It will be appreciated from the earlier section that the type of powder used for the colour modulation of HPMV lamps and designed to absorb blue and near ultra violet radiation would probably

**TABLE IV.**

**Data for various fluorescent compounds used in experimental low-pressure mercury tubular lamps.**

| Compound | Colour | Approx. Dominant Wavelength in Angstrom Units | Efficiency in Lumens per Watt | Relative Efficiencies with equal energies concentrated at each dominant wavelength* |
|---|---|---|---|---|
| Calcium Tungstate... | Blue Violet | 4400 | 20—25 | 2.3 |
| Magnesium ,, | Blue | 4800 | 30—35 | 13.9 |
| Zinc Silicate ..... | Green | 5500 | 80—90 | 100.0 |
| Zinc Beryllium Silicate ..... | Yellow | 5700 | 50—55 | 95.2 |
| Zinc Beryllium Silicate ..... | Orange | 6000 | 45—50 | 63.1 |
| Cadmium Phosphate | Red | 6100 | 45—50 | 50.3 |
| Cadmium Borate ... | Red | 6200 | 30—35 | 38.1 |

* *i.e.*, assuming that the various powders all emit a given amount of energy and that this is concentrated at the dominant wavelength.

not be suitable for lamps of the low pressure type. Certain powders were, however, available which had the requisite properties, and due to intense research since that date quite a useful list of fluorescent inorganic compounds have been developed which are efficiently activated by 2,537 A.U. radiation. (See Table IV.)

The first use of some of these powders was to add to the range of colours available from low-pressure high-voltage cold cathode discharge tubes such as those used for decorative effects and sign work. The range of colours thus made available led to combinations of tubes so related that daylight effects were simulated. The manner in which this desirable result can be achieved is illustrated in Fig. 5.

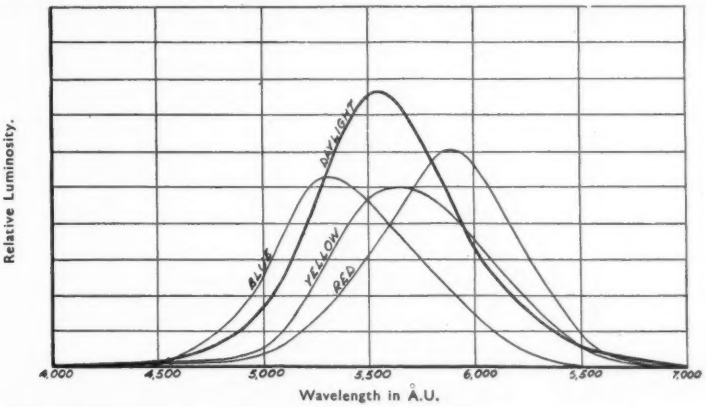


Fig. 5. Light distribution of fluorescent powders and daylight.

The three smaller curves represent the luminosity of blue, yellow, and red tubes. By varying the wattage relationships between tubes of the various colours a combined effect could be produced similar to that shown by the heavier curve which represents the luminosity of daylight. In the earlier work the blue tubing was provided by a coating of calcium tungstate activated by the low-pressure mercury discharge. Yellow light was provided by a coating of zinc silicate on the inside surface of a tube in which the pure neon discharge was taking place and red light was given by a plain neon tube. The utilisation of such combinations for illumination purposes as distinct from effects of a purely decorative nature required that the various coloured tubes should be mounted close together, otherwise highly coloured shadows would result which, although often beautiful, might be objectionable for certain purposes. The ideal arrangement would obviously be one in which the various sources of light were combined into a single tube, and this has now been achieved, as will be described later. An interesting intermediate stage was reached when the combination necessary to produce white light was reduced to two tubes mounted close together. Both tubes were of the low-pressure type, with powder coated on the inside surface and the primary discharge was in each case neon. The fluorescing material in one tube was calcium tungstate and in the other zinc silicate. The tubes appeared pink and yellow respectively, but light was contributed over each portion of the visible spectrum. The advantage of using a neon discharge for activating the powders was twofold, for besides providing light at the red end of the spectrum it was found that the maintenance of light emission was excellent. These results stimulated research in a number of directions which eventually matured in the form of the present mains voltage fluorescent tubes now available in both this country and in America.

## DETAILS OF 80-W. MAINS VOLTAGE FLUORESCENT TUBES AND CONTROL GEAR.

The simplest way of introducing the subject of mains voltage tubes will be to describe the 80-watt lamp type MCF/U. Its general appearance and characteristics are now well known. It is of tubular form, some 5 ft. in length and 1½ in. in diameter, and emits when new 2,800 lumens for a net consumption of 80 watts. A full table of characteristics is given below, and some of these will repay further study:—

**TABLE V.**

**Data for Cold White Fluorescent Tube Type MCF/U.**

| | |
|---|---|
| Length | 60 ± 0.5 in. |
| Diameter | 38 ± 1.5 mm. |
| Cap | B.22/25 x 26 |
| Nominal lamp watts | 80 |
| Arc length | 1,445 ± 10 mm. |
| Lamp operating volts | 115 ± 10 |
| Nominal lamp operating current | 0.8 amps. |
| Initial efficiency | 35.0 L/W. |
| Average life | 2,000 hours |
| Supply volts | 200 — 250. |

Figure 6 gives a general view of the lamp.

The MCF/U lamp consists of a glass tube which has emissive electrodes sealed into its ends and a coating of fluorescent powder on its inner surface. It contains a gas-filling consisting of a very low pressure of argon together with a small amount of mercury.

Fluorescent light sources of this type are designed to play such an important part in the lighting of the future, and have features which are of such general

Fig. 6. 5-ft. Fluorescent Tube Type MCF/U.

interest that it will be useful to consider their various aspects in some detail. Convenient sections in which to do this are given below:

(1) Operating circuit.
(2) Electrode system and tube characteristics.
(3) The fluorescent powder layer and its light emission.
(4) Control gear.

### (1) Operating Circuit.

It is necessary to operate electric discharge lamps in series with some form of current limiting device. The 80-watt MCF/U lamp is not an exception to this general rule, and due to its considerable length and the fact that it is designed for operation from ordinary mains voltages an automatic starting switch is generally provided to assist in the production of a high voltage impulse to initiate the discharge. A schematic diagram of the essential circuit elements is shown below.

It will be noticed that the tube electrodes which are designed for series heating are connected to the contacts of the bayonet cap at each end. The current limiting device is in series with one electrode, the other end of the same electrode being connected via the starting switch to the electrode at the opposite end of the tube. The circuit is completed by connecting the remaining free electrode end and the free choke connection to the A.C. mains. In the diagram above the switch is shown as a simple on and off type. An ordinary tumbler switch is quite suitable for manual operation. In practice, an automatic switch is provided, and a discussion of switch types and characteristics is given in Section (4).

### (2) Electrode System and Tube Characteristics.

The electrode of the 80-watt MCF/U lamp consists of a cathode coil of tungsten wire impregnated with active material and mounted on a pair of electrodes which are extended alongside the tungsten coil to form the anode. A view of this arrangement

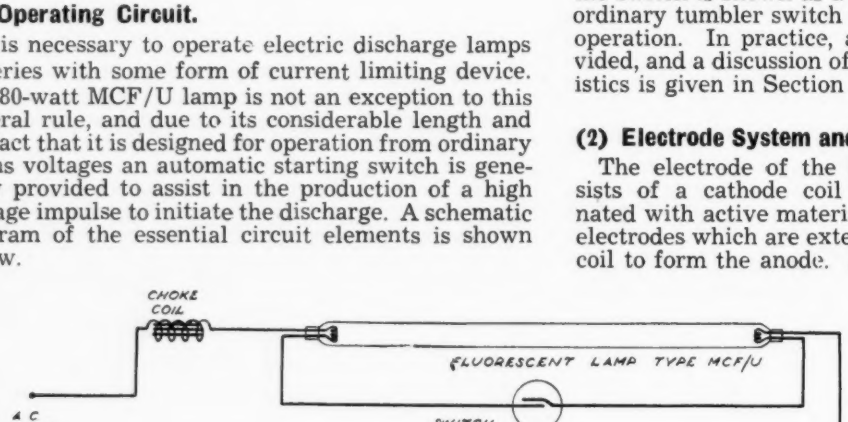


Fig. 7. Circuit elements for operation of low-pressure Fluorescent Lamp Type MCF/U.

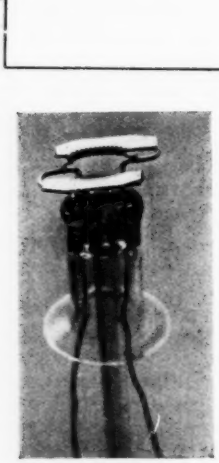

Fig. 8. Electrode arrangement of 80-watt low-pressure tube.

is shown in Fig 8. The cathode coil is designed to reach an emitting temperature with a current of about 1.2 amperes, and with this current flowing to have a voltage drop across its ends of about 10 volts. As a matter of fact, the volt ampere curve of one of these electrodes will repay study. (See Fig. 9.) It will be seen that from 0 to about 9 volts the current rises in a fairly linear relationship with voltage. At higher current values the volt drop across the electrodes rises much less rapidly, and in fact the electrodes begin to develop characteristics similar to that of a voltage stabiliser. This phenomenon is due to the development of a gas current in parallel with the current carried by the electrode coil itself. At low voltages, and therefore at low electrode temperatures, the gas current is almost negligible, but in the neighbourhood of 9 volts the gas current rises rapidly. Above 9 volts the gas and mercury vapour in the

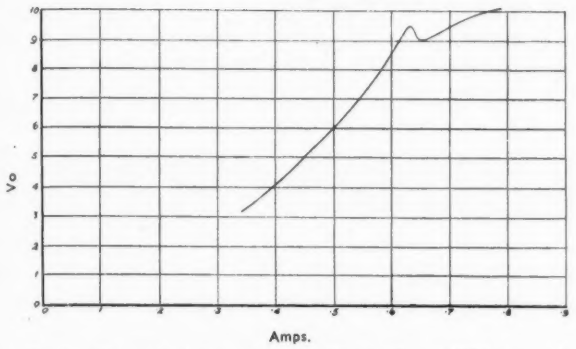


Fig. 9. Electrode characteristics of 80-watt Type MCF/U Lamp.]

atmosphere surrounding the electrode becomes ionised and current flows in two parallel paths across the electrode ends, the first component of the current being that carried by the tungsten wire, the second component being that carried by the ionised gas. This effect explains the development of a glow round the electrode ends when the tube is first switched into circuit and before the starting switch opens. The ionised gas and mercury vapour produces sufficient ultra-violet radiation to excite the fluorescent powder for an inch or two from each end. When the starting switch opens a voltage surge is produced which starts the tube, the ionised gas at each end assisting in the process and ensuring reliable ignition of the discharge. It will be appreciated that on starting from cold, the tube temperature rises slowly until the equilibrium value is reached. During this warming-up period the light output also rises, as shown in Fig. 10. This effect is very interesting, as it occurs simultaneously with changes in the electrical characteristics of the tube. It will be seen from Fig. 10 that the tube voltage gradually falls until temperature equilibrium is reached, and consequently the tube watts fall slightly. All these effects are due to the fact that when the tube is first switched on a proportion of the current is carried by argon ions, and as the temperature increases the concentration of mercury ions increases, and the proportion of the total current carried thereby gradually reaches a maximum. This maximum corresponds with a tube temperature of approximately 45° C. At higher temperatures the light output falls off, due to absorption of the mercury resonance radiation, which increases progressively at mercury vapour pressures above about 0.009 mm., corresponding with a temperature of 45° C. As the fluorescent powder layer is designed to be preferentially activated by the mercury resonance radiation, a decrease in the proportion of radiation at this wavelength causes a decrease in the brightness of the powder, hence a reduction in light output.

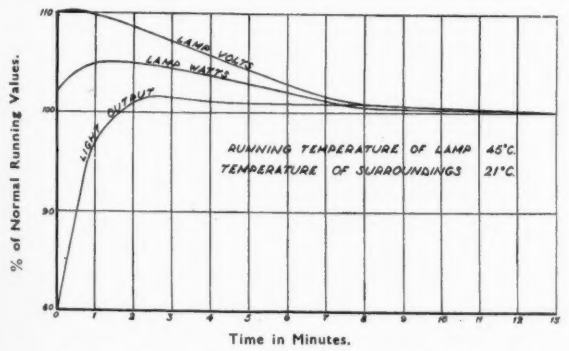


Fig. 10. Characteristics of 80-watt Type MCF/U Lamp.

Co-operation is therefore necessary between the lamp maker and the fittings designer. The former must design the 80-watt MCF/U lamp to reach the operating temperature corresponding with optimum efficiency, while the latter must understand the lamp characteristics in order to avoid fitting designs which would give rise to excessive tube temperature.

### (3) The Fluorescent Powder Layer and its Light Emission.

It has been indicated above that the fluorescent powder layer consists of an intimate mixture of several powders, each contributing a proportion of the emitted light. The component powders are so proportioned and chosen that a light approximating closely to north daylight is produced. The powders, which separately would give blue, yellow, and red light, are used as an intimate mixture the grain size of which is so small that the eye cannot distinguish separate colours and a white light only is seen. This is a most interesting effect.

The spectrograms in Fig. 11 show the fluorescence of a selection of substances all strongly activated by energy radiated at about 2,537 A.U. It must be realised that the exact response of a particular powder is to some extent dependent on its method of preparation. The spectrograms are, however, typical of the response obtained with powders suitable for use in the 80-watt MCF/U lamp. It will be seen that in most cases the fluorescent light appears as a single structureless band covering a fairly wide region of the visible spectrum. In the case of calcium tungstate, and to some extent magnesium tungstate, the fluorescent radiation extends well into the near ultra-violet region. It is interesting to notice also that there is little or no absorption of the 3,650 A.U. line, thus sharply differentiating these powders from the sulphide group.

Each particle in the powder layer glows with its characteristic colour and under a low power microscope the powder surface of the MCF/U lamp appears like star dust rainbow hued. It is possible by varying the proportion of the component powders to vary the colour of the emitted light. Strict control is therefore necessary at each stage of manufacture to ensure a colour which remains constant within close limits. From a wide range of possibilities the present colour appears most satisfactory for general factory lighting and similar purposes. The distribution of luminosity is shown in the block diagram (Fig. 12), which also gives a comparison with noon

daylight. The method of production of these block diagrams deserves mention, as this form of representation can be used for indicating the colour and assessing the colour rendering properties of any light source. A pure spectrum of the light source under test is produced by suitable apparatus and arranged to fall on a photo-electric cell connected with a sensitive galvanometer. It is important that the photo-electric cell should have a response closely similar to the luminosity curve of the normal eye. A series of

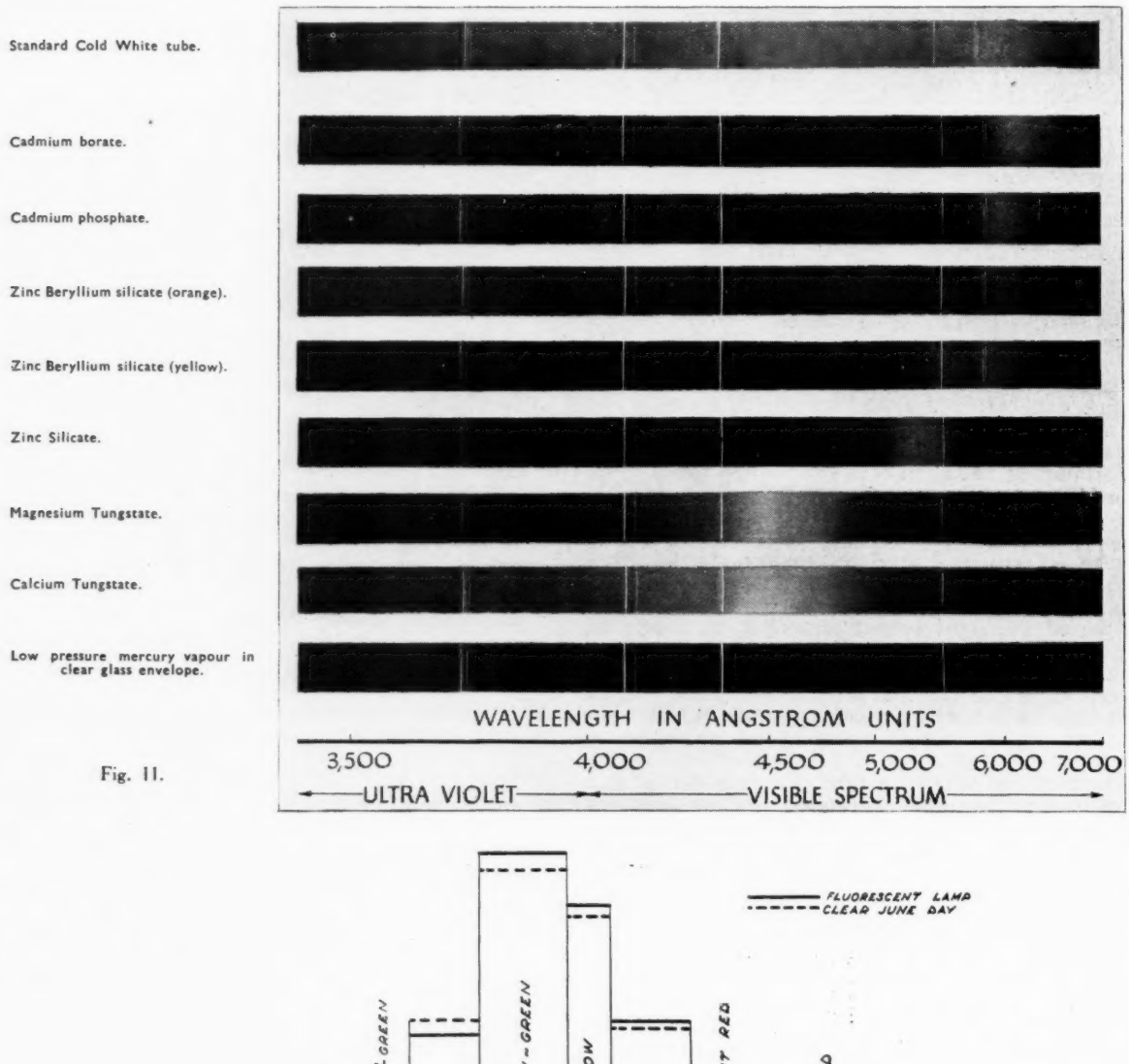


Fig. 11.

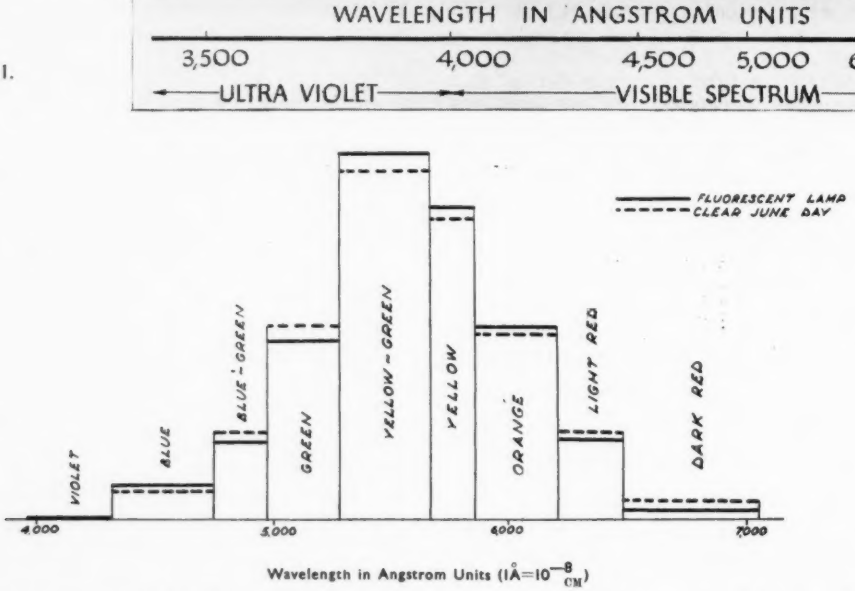


Fig. 12. Spectral luminosity distribution of the Fluorescent Tube compared with that of noon sunlight on a clear June day.

masks subdividing the visible spectrum into eight bands are interposed in turn into the spectrum beam so that the luminosity in each of the following wavebands can be calculated from the readings of the galvanometer. Table VI. gives the wavebands and luminosity results for typical blue, green, yellow, and red fluorescent powders. From the results of such measurements and a knowledge of the relative brightness of the various powders it is possible to calculate combinations for a wide range of hues. The relative luminosity figures for the 80-watt MCF/U lamp are given in column 5.

**TABLE VI.**

**Spectral Luminosity Data for Various Fluorescent Powders**

| Wavelength Bands in Angstrom Units | Magnesium Tungstate | Zinc Silicate | Yellow Zinc Beryllium Silicate | Cadmium Chloro Phosphate | Standard Cold White |
|---|---|---|---|---|---|
| | | Percentage Luminosity | | | |
| 4000—4200 | .022 | — | — | — | .012 |
| 4200—4400 | .52 | .12 | .18 | .02 | .38 |
| 4400—4600 | .70 | .05 | .17 | .01 | .50 |
| 4600—5100 | 14.20 | 5.90 | 1.70 | .85 | 7.40 |
| 5100—5600 | 52.00 | 77.70 | 38.90 | 19.80 | 41.50 |
| 5600—6100 | 27.70 | 14.80 | 45.80 | 60.60 | 40.30 |
| 6100—6600 | 4.50 | 1.13 | 12.30 | 17.90 | 9.25 |
| 6600—7200 | .02 | .10 | .40 | .60 | .33 |

### (4) Control Gear.

The function of the control gear which is used for this type of low-pressure lamp is threefold: (i.) A choke is used to limit the lamp current to the desired value; (ii.) a starting switch is provided for initiating the discharge; (iii.) condensers are provided, viz., a radio suppressor condenser across the switch contacts and a power factor correction condenser across the mains leads.

(i.) CHOKE.—In a paper of this type little requires to be said on the subject of the current limiting choke. It is important, of course, that this choke should have the correct electrical characteristics and that it should have insulation between turns and to earth adequate to withstand the surge voltages produced when the starting switch opens. It is important for the choke to be so arranged that the electrodes are not overheated during the period before the starting switch opens, and also that the tube current is maintained at the correct value of 0.8 amperes during normal running.

(ii.) STARTING SWITCH.—The function of the starting switch is to provide a short period for preheating the electrodes to an emitting temperature and to cause the production of a surge voltage sufficient to ignite the tube. As electrodes are designed to reach an adequate emitting temperature on the choke starting current in one to two seconds, starting switches are usually designed to remain closed for a second or two and then to open sharply so that an inductive surge is produced, due to interruption of the choke current. This inductive surge is impressed across the tube electrodes and must be of sufficient magnitude to initiate the discharge. Three types of starting switch will be mentioned, each of them having distinctive features:—

(a) The thermal switch.
(b) The thermal glow switch.
(c) The magnetic switch.

(a) *Thermal Switch.*—This type of switch is mounted inside a small tubular bulb, as illustrated in Fig. 13. It is connected in circuit as shown in Fig. 14.

A bimetal element "A" carries a contact "B." The element "A" is bent so as partially to enclose a heating element "C," consisting of a short low-resistance nichrome helix. A stationary contact "D" is carried by a second bimetal element "E,"

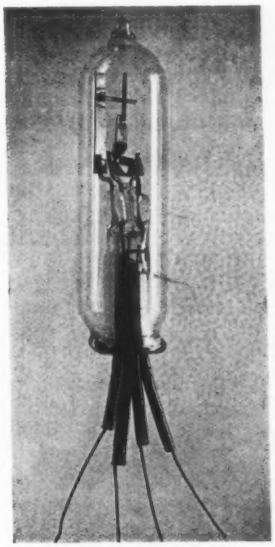

Fig. 13. Thermal Switch.

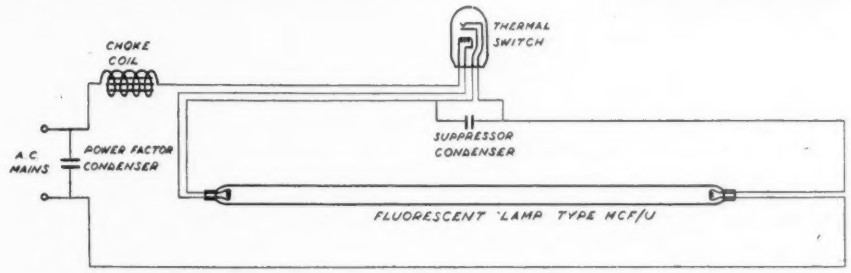


Fig. 14. Thermal Switch in circuit for operation of 80-watt Fluorescent Lamp Type MCF/U.

which serves to compensate for ambient temperature changes. The arrangement is shown diagrammatically in Fig. 15. The switch contacts "B" and "D" are normally closed, and are connected across one

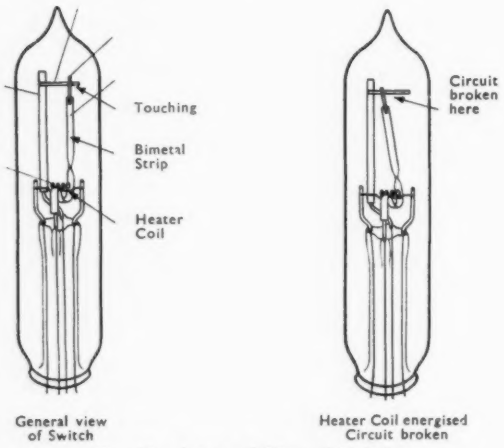


Fig. 15. Action of Thermal Switch

end of each of the lamp electrodes as shown in Fig. 14. The heater element "E" is connected in series with the choke. This type of switch requires four current-carrying leads. The contacts open by the passage of current through the heating element "E," and remain open while current flows through the choke via the tube. On cessation of the flow of current the switch contacts "B" and "D" close, the tube is shorted out, and on remaking the circuit current flows through the electrodes, raising them to incandescence. The switch contacts "B" and "D" reopen after about three seconds, and the inductive kick so produced is adequate to restart the tube.

(b) *Thermal Glow Switch.*—In this type of switch, one form of which is shown in Fig. 16, a bimetal element (1) carries one contact, another contact being provided on a fixed electrode (2). The electrode system is mounted in a glass tube, which is filled with a low pressure of neon, helium, or other suitable gas. The switch contacts are connected

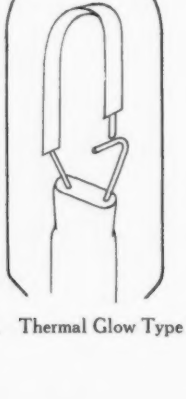

Fig. 16. Thermal Glow Type Switch

across the tube electrodes and in its normal position the switch is open. The operation is as follows:—

When the tube circuit is closed the mains volts are impressed across the switch contacts and a glow discharge results. A fairly heavy current is passed, the bimetal element heats up and is arranged so that the switch contacts close. The heating effect then ceases, the switch contacts therefore open, producing an inductive kick which is sufficient to start the tube. The voltage now impressed across the switch contacts is, of course, equal to the tube voltage and is normally about 115 volts, which is insufficient to cause a cathode glow. The switch therefore remains open until the tube is extinguished. On remaking the circuit the above cycle of operations is repeated.

(c) *Magnetic Switch.*—Various types of magnetic switch have been suggested, some of which have interesting possibilities. For example, it is possible to use the stray flux at the choke air gap to actuate a light spring loaded armature carrying contacts which, when the choke is unenergised, closes the series circuit of the electrodes as in other forms of switch which have been described. Immediately current flows through the circuit the switch opens and closes very rapidly, producing a series of voltage impulses and at the same time causing the electrodes to be heated to an emitting temperature. Within a very short period the tube strikes up. The switch contacts then remain held open by the magnetic flux

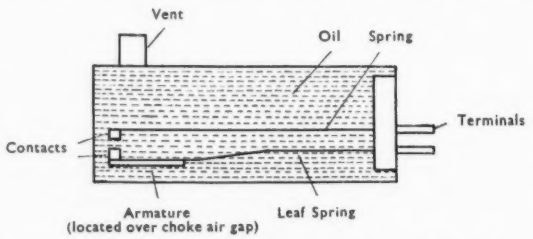


Fig. 17. Diagrammatic representation of a Magnetic Switch.

of the choke. Various designs of switch have been worked out employing this principle, and one experimental form of oil-immersed switch is shown in Fig. 17.

The fact that a voltage surge is required to start this type of lamp has been mentioned several times, and it is interesting to study the magnitude and characteristics of the voltage impulses produced by the various types of switches which have been referred to. The figures given do not pretend necessarily to settle the question as to which of the three types of switch is preferable, but they do indicate the magnitude and type of voltage impulses produced by particular designs of the thermal, thermal glow, and magnetic switches.

The magnitude of these transient voltages depends on the instant at which the switch opens. As far as could be ascertained from a visual inspection of a cathode ray oscillograph the maximum transient voltages obtained with the different switches, tested with a .04 microfarad condenser connected across

them in each case, were approximately as shown in the following table:—

| | |
|---|---|
| Thermal switch ..... | 750 volts |
| Thermal Glow switch ..... | 1,000 „ |
| Magnetic switch ..... | 1,250 „ |

These values did not appear to be appreciably affected by the capacity of the condenser used.

Typical oscillograms for the various types of switches are shown in Fig. 18. These have been drawn from the mental impression obtained from

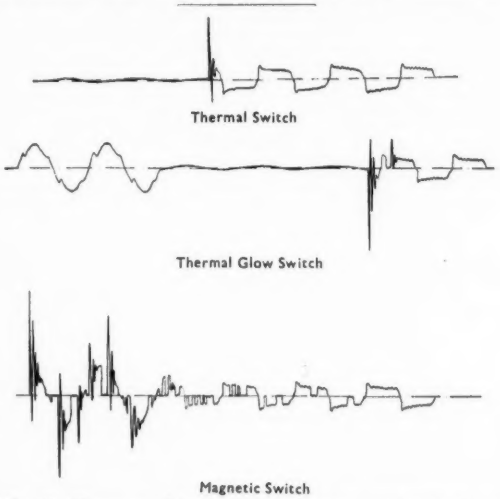


Fig. 18. Oscillograms showing starting surges produced by various types of control gear for 80-watt Type MCF/U Lamps.

successive observations made with each type of switch. The delineations represent in each case the sequence of events, but do not necessarily show the lapse of time between one event and the next. In the case of the thermal glow switch, for instance, the period between closing and reopening is longer than that represented by the practically straight line of zero mean voltage shown. In the case of the magnetic switch the peaky voltages shown over a period of two cycles are actually present over a period of possibly a second or more.

(iii.) CONDENSERS.—Suitable values for 80-watt MCF/U tubes are 0.05 mfd for the radio suppressor and 8.0 mfd for the power factor correction condenser.

## APPLICATION OF LOW-PRESSURE TUBULAR FLUORESCENT LAMPS

During the past two years one dominant consideration has influenced the application of low-pressure fluorescent tubular lighting in this country, namely, the necessity for providing a standardised industrial lighting unit capable of being produced in quantities sufficient for the demands of industry almost entirely engaged on war production. It is a matter of some satisfaction to the electric lamp manufacturers concerned to know that coincident with the need for a day and night industrial output, often in totally blacked-out factories, the 80-watt MCF/U lamp was already sufficiently developed to enable it to be marketed in March, 1940.

During the two years which have elapsed since its introduction, the 80-watt lamp has proved of immense value for industrial lighting, and it has been installed not only in new factories but also to replace existing lighting installations where the standard of illumination was inadequate for present-day conditions.

Prior to the introduction of the fluorescent lamp it would be generally true to say that improvements in electric lamps resulted simultaneously in increases in source brightness. At a certain stage the developing science of illuminating engineering began to exercise its important functions and to show the best way of utilising light sources so that the maximum benefit could be derived from their use. The development of the low-pressure lamp marks a unique step not only for reasons such as the high efficiency, colour qualities or long life which can be obtained, but because the source brightness is low enough to enable new standards of illumination to be applied commercially. The fitness for purpose of these fluorescent lamps is especially noteworthy when one considers how the requirements of the lamp designers and those of the illuminating engineer are merged together.

Low source brightness is particularly advantageous in industry where in many cases it is impossible to avoid the use of brightly polished machine parts and large surface areas of high reflectivity from which source images may reach the worker's eye. In the case of installations with high brightness sources these images often have disastrous effects on visual acuity, and are a potent cause of eye strain. It is acknowledged that in a well designed incandescent lamp installation such effects can be reduced to a minimum, but the ease with which they are overcome in a fluorescent lighting installation generally comes as a revelation to those seeing a large installation for the first time.

It is interesting to compare American practice with that in this country. During the first two years of war, while developments in fluorescent lighting in this country had been confined by common consent to a standard size and colour of lamp, in America, where the need for such restrictions had not yet arisen, amazing developments took place in the use of this new form of lighting. A range of lamp sizes and wattages have been made available, and most of these are obtainable in the form of coloured tubes as well as in two variants of so-called white light. It is interesting to note that it is the white tube which is the most popular, and the tendency appears to be that the greatest demand will develop for lamps rated at wattages of the same order as the standard English tube, notwithstanding the fact that the first lamp marketed in America was rated at 25 watts and was much smaller in size. Certain factors are worthy of mention which contribute to the unique place which these lamps are already filling in industrial lighting installations and which justify the belief

that they will find use in a rapidly extending field when conditions return to normal.

The low surface brightness of approximately 0.5 stilb renders the 80-watt MCF/U lamp eminently suitable for use with simple reflectors of both concentrating and dispersive types without the need for any intermediate diffusing medium. It is important, however, even with this low order of brightness, to avoid the use of unshielded lamps at or about eye level, otherwise due to the large projected area of the source (0.625 sq. ft. in the case of the 80-watt lamp) discomfort glare may be experienced.

Typical industrial lighting fittings are shown in Fig. 19 (a), (b), and (c). It will be seen that these fittings are of a simple functional type allowing for ease of cleaning and maintenance. Polar curves of the fittings shown in Fig. 19 (a) and (c) are given in Figs. 20 (a) and (c).

Most industrial type reflectors are designed to provide a large area of low brightness enabling the production of a general effect not dissimilar to that produced from a good natural roof light. Shadows are therefore reduced to low intensity and the effect on the light distribution of a moderate amount of overhead pipework can generally be ignored. Sometimes, however, cases are experienced in which there

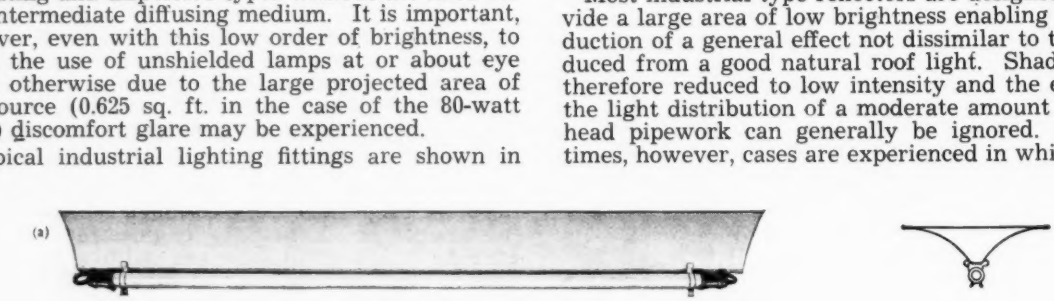


Fig. 19. Industrial Fittings for 80-watt Fluorescent Lamp Type MCF/U

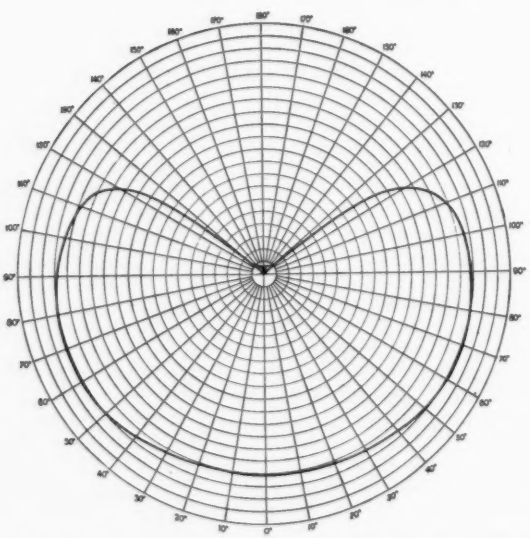

Fig. 20 (a). Distribution of Light from an 80-watt Fluorescent Tube in a Distributive Type Reflector shown in Fig. 19 (a).

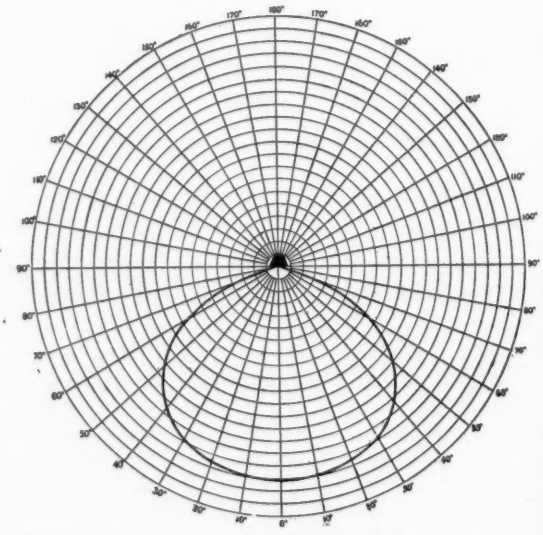

Fig. 20 (c). Distribution of light from an 80-watt Fluorescent Tube in a Dispersive Type Trough Reflector shown in Fig. 19 (c).

is a considerable amount of pipe-work and other equipment lying parallel and near to the lamp axis. In such cases it is advisable to arrange a proportion of the lighting fittings at right angles to the main direction of distribution. In America in some cases tubular fluorescent lamps have been arranged diagonally particularly when small workshops and offices are being illuminated. This special arrangement has the advantage of cutting down the intensity of shadows occurring in one direction on benches which would normally be located parallel to the main walls of the room.

Fluorescent lamps are well adapted for use at low mounting heights, although this is by no means necessary. It does, however, enable the production of high illumination values on vertical surfaces—a factor often of great importance in industry.

Since the advent of electric discharge lamps into industry the question as to whether stroboscopic effects on moving machine parts would be of any importance has given rise to some study. Due to the phosphorescence of most of the powders used in the production of 80-watt MCF/U lamps stroboscopic effects are much less noticeable than would be the case with a mercury or sodium discharge lamp installation. It is, however, desirable wherever possible to wire the lighting fittings on a three-phase distribution according to one of the well-known arrangements and so to practically eliminate stroboscopic flicker.* A similar result can be obtained on a special two-lamp circuit from a single-phase supply, one of the lamps in the fitting being operated with inductance control and the second lamp on a capacitance control unit. With this arrangement the currents through the two lamps are practically 90° out of phase, and the changes in light output due to the cyclic changes in the current value through the tubes are largely compensated.

A consideration of importance to the lighting engineer is the effect of ambient temperature on the lamp efficiency. As was indicated in an earlier section very low or very high temperature conditions will result in a decrease in the light output of the fluorescent lamp.

It may be shown that the type of powder used in low-pressure fluorescent lamps and which is mainly activated by 2,537 A.U. radiation is practically unaffected by temperature over the range likely to be met with in industrial lighting installations. The temperature efficiency characteristic of the lamps is, therefore, dependent only on changes in the effectiveness of transformation of electrical energy into radiation at 2,537 A.U.

The magnitude of the efficiency changes resulting from changes in ambient temperature are shown in Fig. 21. It will be seen that the maximum efficiency is developed at about 15° C. ambient and that the slope of the efficiency temperature characteristic is greatest at temperatures below 15° C. In this region the pressure of mercury vapour is too low for maximum production of 2,537 A.U. radiation, and non-effective energy conversions are occurring in the rare gas-filling of the lamp. At temperatures in excess of 15° C. absorption of 2,537 A.U. radiation occurs progressively with increase of temperature, resulting in the emission of radiation less effective in exciting the fluorescent powder layer and therefore a decrease in the efficiency of light production.

It follows from the above that account has to be taken of a complex series of inter-related factors to produce a lamp design which develops its maximum efficiency at the temperatures normally available under good industrial conditions. Similarly, the fittings designer must be aware of the lamp characteristics to ensure the development of the maximum lamp efficiency and its most adequate utilisation. Special care is necessary in the design of fittings embodying two or more lamps side by side or in fittings of a totally enclosed type to prevent excessive rise in tube temperature which would have the effect of somewhat reducing the total light output.

The effect of voltage variation on light output and performance are also of importance, and in Fig. 22 the effect of a ± 5 per cent. change in applied voltage is shown to correspond with less than ± 5 per cent.

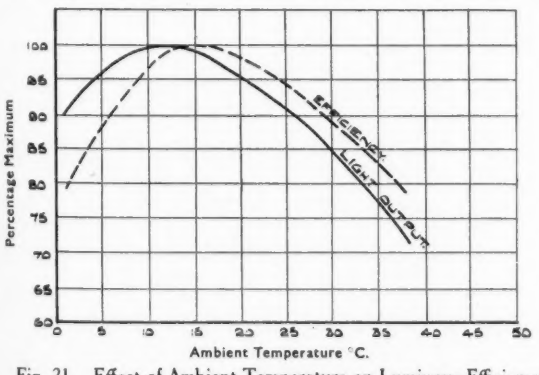


Fig. 21. Effect of Ambient Temperature on Luminous Efficiency and Light Output of 80-watt Fluorescent Tube

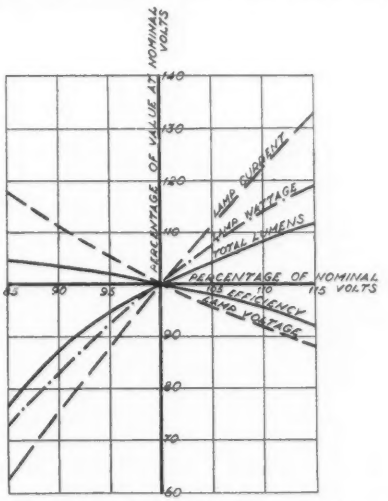


Fig. 22. Effect of Variation of Mains Voltage on Characteristics of 80-watt Fluorescent Tube

*See, for example, "Stroboscopic Effects from Discharge Lamps," by J. N. Aldington, "Electrical Times," 23.9.37.

change in light output. This is an extremely low figure due to certain self-compensating effects in the lamp and control circuit. For a tungsten filament lamp corresponding values would be ± 17 per cent. change in light output for a ± 5 per cent. change in voltage. When operated under normal conditions the 80-watt fluorescent lamp has an average initial efficiency of 35 L/W which falls to 32 L/W after 100 hours. Thereafter the rate of change of efficiency with time is much less rapid, and at 2,000 hours the average efficiency of these lamps is 24 L/W. A number of causes can contribute to the determination of the life of any particular lamp. Experience has shown that the shape of the survivor curve for these lamps is similar to that of other devices of a similar nature, and the average life of 2,000 hours is based on data taking into account not only the lamp survivor curve but also the lumen maintenance characteristics.

One general point is worthy of mention in view of the wide adoption of this new form of lighting and its future prospects. Failure in the case of a filament lamp is generally occasioned by the lamp filament having reached its appointed end, and diagnosis is simple. In the case of fluorescent lamps, however, where the most general cause of ultimate failure is loss of emission from the electrodes a " blinking " or " hunting " effect may be the first sign of the need for a new lamp. Lighting engineers and users must recognise this effect and arrange to replace or switch off the lamp without delay to avoid the possibility of damage to the starting switch. It will, of course, be understood that in the case of the supply voltage being too low this effect may occur with a perfect lamp and hence care must be taken in the diagnosis of the fault.

## CONCLUSIONS.

In the preceding sections of this paper attention has been devoted almost entirely to reviewing the main lines along which progress has been achieved in the development and application of practical fluorescent light sources. No one should conclude therefrom that the developments which have been mentioned have proceeded in the direct manner in which they have been described, or that they are the only lines along which work has been done or progress achieved. Much interesting material had necessarily to be excluded from this paper owing to the very wide scope of the subject. Some mention will, however, be made in this concluding section of certain other developments which might become of increased importance in the future.

The use of large areas of fluorescent material continuously irradiated by energy of appropriate wavelength must not be disregarded as a possible source of illumination for special purposes. At the present time the so-called black glass lamp is the only practical source of ultra-violet radiation for such a purpose, and as its effective energy lies in the region between 3,000 and 4,000 A.U. suitable phosphors are to be found among organic dyestuffs or the metallic sulphides. Use has already been made of this combination of lamp and phosphor in theatre work and for advertising and display. The low overall efficiency of the combination, however, tends at the present to exclude its use for general illumination purposes. Difficulties arise in the utilisation of radiant energy of lower wavelength which would enable the range of possible phosphors to be extended tremendously, but these difficulties are of a kind which need not be regarded as insoluble.

The use of rare gases and metals other than mercury for producing the primary radiation has received some study, and the possibilities are by no means exhausted. Whereas the positive column or the arc is the principal source of radiation in most practical forms of discharge lamp used for exciting fluorescent substances, ultra-violet radiation can be produced from the glow discharge, and some interesting results have been achieved both of the type in which fluorescence is used to modulate the primary light and that in which fluorescence is the dominant effect. The tungsten filament operating at high temperatures is also a sufficiently powerful source of near ultra-violet and violet radiation to activate quite strongly certain fluorescent materials.

The fluorescent light sources which have been described have opened up new possibilities for the lighting engineer. There are indications that the progress which has been made marks the beginning of a new era in the development and ultilisation of light sources probably as important as that which followed the advent of the gas-filled tungsten filament lamp.

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" The Radiation from Artificial Illuminants," by Aldington, J. N. Assoc. of Public Lighting Engineers, September, 1938.

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" The Photometric Properties of Some Luminescent Materials," by Harper, W. E., Robinson Margt, B., and Bowtell, J. N. Trans. of the Illum. Eng. Soc., June, 1940.

" Electric Discharge Lamps," by Francis, V. J., and Jenkins, H. G. G.E.C. Publication, July, 1941.

# DISCUSSION

The PRESIDENT, remarking that even in war-time if the subject of the paper was of sufficient interest it was possible to attract large audiences, welcomed members of the Institution of Electrical Engineers. Mr. Aldington was a master of his subject and also a keen research worker. It was to be hoped that during the course of the discussion other workers doing research on this subject would express their views. He recalled that a paper on a similar matter would be presented at the meeting of the Installations Section of the Institution of Electrical Engineers later in the week.

The PRESIDENT remarked later that in the major part of the lecture hall there was an illumination of 50 ft.c. and in other parts it was of the order of 100 ft.c. He predicted that when the war was over such levels would become quite usual. Therefore, it was significant that in this new light source there were opportunities of using light in greater abundance, free from glare and with benefit to vision.

Mr. H. R. RUFF, one of the authors of the I.E.E. paper mentioned by the President, after congratulating the author for his most interesting paper, asked for further information with regard to the surge voltages obtained in the tests of different types of starting gear. The author had mentioned surge voltages of 750 volts, 1,000 volts, and 1,250 volts for circuits with thermal, glow, and electro-magnetic switches respectively. From similar measurements it appeared that these voltages had been measured with a normal lamp in circuit and that they were thus the starting voltages required by the lamp under these three conditions and not the maximum surge voltages that could be obtained from the switches.

In tests made in the B.T.H. Research Laboratories to measure the maximum surge voltage obtainable from the starting circuit, use is made of two fluorescent lamps, one electrode of each being connected in the circuit, to simulate the condition of a lamp requiring the greatest possible surge to strike it. Under these conditions maximum surge voltages of 3,500 volts for some thermal switches and 2,000 volts for some glow switches have been measured. It might be expected that the thermal starter switch would give a higher voltage because the contacts open in an atmosphere of hydrogen, well known to be an arc quenching medium. With a normal lamp in circuit the surge voltage is generally limited and determined by the striking voltage of the lamp. The higher the temperature of the electrodes the lower the voltage surge necessary to start the lamp.

Thus we should rather interpret the author's measurements as indicating that the lamp struck rather more easily with the thermal switch, and we should be glad if the author would state if a normal lamp was in circuit when the surge measurements were taken.

Dr. J. W. T. WALSH brought a message from Mr. H. T. Young, the chairman of the Installations Section of the Institution of Electrical Engineers, expressing his regret that he was unable to be present at this meeting. Mr. Young would, he said, be pleased to hear that so many members of the Installation Section were present.

Referring to the paper, Dr. Walsh said that one point which interested him particularly was the way in which a mixture of powders acted to produce the sensation of white which was obtained in the standard form of tube.

The author had also made the point that the white light given by these lamps was not adequate for real colour matching purposes. Presumably he meant that it would not satisfy the requirements of the British Standard Specification for colour matching sources. It would be interesting to know whether the author felt that, with a little more research, we might expect a lamp in which there was a special coating to give the performance required by the specification and to give a really close imitation of daylight. That might make possible some tightening up of the specification.

Mr. R. O. ACKERLEY, referring to what the author had said with regard to the small change in light output in relation to voltage variation, said it was very often overlooked that there were two forms of voltage variation. There was the variation which took place throughout the day from hour to hour and there was the permanent difference between the declared rated voltage and the actual voltage in the building which might exist at any time. All forms of discharge lamp had the advantage that it was possible to make adjustment at the chokes for variations in the actual voltage compared with the declared voltage so that there was an advantage beyond that which the author had mentioned.

He asked if the author had experienced cases in which the stroboscopic effect from the fluorescent lamp was an actual disability. Personally he had never met one, and he regarded this as one of the bogies that ought to be countered if possible.

Further, was there a tendency for these lamps to change colour during life and was that change apparent in the appearance of the lamp or was it apparent in the colour rendering of articles illuminated by it? Very often two lamps looked different, but when they were applied to some coloured fabric or some engineering job they seemed to give exactly the same sort of effect.

Although mention had been made of the glareless effect of these lamps and their low-surface brightness, he imagined the author would advocate, where the lamps were mounted low, that they should have some sort of screen. It was perhaps not so much a question of brightness as the volume of light that reached the eye, and he felt that people should be warned, when using these lamps mounted very low, to have some reflector or diffusing medium such as opal glass.

Finally, Mr. Ackerley said the author had not brought out the important point of the psychological effect of the closeness which these lamps had to daylight. This was not only useful from the colour rendering point of view, but it had great psychological advantages in the comfort the light gave under industrial conditions.

Mr. F. C. RAPHAEL, remarking that he was particularly interested in hospital lighting, asked whether these lamps were absolutely silent. There was a hum in the lecture-room at the moment which was possibly due to the ventilation and not the lamps which were being demonstrated, but hum was a possibility in connection with these lamps, and that would prevent their being used in certain positions.

Mr. F. A. LAWSON said it was an astonishing fact which the author had brought out that these fluorescent powders gave an efficiency of 35 to 50 lumens per watt. A great deal had been said about the 2,537 wave-length, and it would be interesting to know whether it was a matter of chance that these powders were fluorescent at that wave-length and did this fluorescence vary as the wave-length varied. He believed that argon was used as a starting gas. Was there any reason for the selection of argon rather than the argon/neon mixture used in the high-pressure lamps?

Mr. A. G. RAMSEY remarked that as a user he would like to make a plea to the designers of fittings that fittings for these lamps should be designed scientifically and not only for aesthetic or appearance reasons. In the past there have been produced legions of fittings which have no real scientific design and, indeed, have not been artistic in their effect.

With regard to the point mentioned by Mr. Raphael concerning the use of these lamps for hospital theatre lighting, they had been tried out fairly successfully, and the hum complained of was removed by placing the chokes outside the theatre.

Mr. A. CUNNINGTON asked whether these lamps could satisfactorily be applied in a telephone exchange where there was apparatus of a type that might be sensitive to the sort of emission that takes place in the fluorescent lamp circuit.

Mr. C. BARON said that as the representative of a supply company he was extremely interested in the question of power factor. He believed it was customary for manufacturers to show in their catalogues and publicity literature the power factor condenser as a separate item, but he could imagine purchasers, with a view to limiting their capital costs, omitting to order the condenser equipment. The supply people might ultimately find difficulty in facing up to

the results of that sort of thing if the success forecast for these tubes became an accomplished fact—of which he had no doubt in his own mind. Therefore, he seriously suggested to the manufacturers of equipment that the choke should in future be regarded as inclusive of the power factor condenser and should be listed and sold at an inclusive price instead of with the condenser as a separate item. He also asked if there was a commercially marketable capacitance of some kind which could be used with alternate lamps to correct power factor, and was it purchasable from the equipment manufacturers?

Mr. J. S. Dow asked if the author could confirm what he had been told recently, viz., that these lamps suffered from extreme cold such as we had experienced last winter. In these circumstances they were said to be a little difficult to get going. He recalled one instance in which the user had got over that difficulty by giving the lamps a stroke with a warm cloth in the morning.

Could the author give any guidance on a question which had been discussed at a recent meeting of the society, i.e., the effect of shadows from these lamps in a drawing office. It appeared that troublesome shadows were cast if the lamps were parallel to a straight edge, such as that of a ruler or, in a shop, the edge of a tool. The difficulty could be overcome by assigning appropriate positions to the lamps, or by methods of diffusion. Could the author hold out hope that ultimately these lamps would be produced as symmetrical sources, possibly in the form of a ring which would get over these directional shadow difficulties, besides giving a more pleasing appearance?

In the course of the discussion other speakers asked for particulars of the life of these fluorescent lamps, as compared with tungsten filament lamps, and inquired whether some use could not be made of the 5 ft. of glass tube that remained when the lamp gave out. Further explanation was also sought for the rapid falling off in candlepower during the initial period of life. It was also asked whether it would be possible, in a big installation, to run lamps in series, having separate exciting coils, so as to reduce the cost of the chokes required.

Mr. C. A. HUGHES (chairman of the E.L.M.A. Council) said that the E.L.M.A. Lighting Service Bureau was delighted to welcome to their premises the members of the Illuminating Engineering Society and of the Institution of Electrical Engineers. The facilities available for demonstrations were gladly placed at the disposal of all those interested in lighting because it was realised that these demonstrations were of great practical value. One of the objects for which his association had been formed was to ensure an interchange of technical information between the various laboratories, as the manufacturers regarded themselves as having some responsibility to the public in providing light in the best possible form and at the lowest possible cost. Whilst it was true that the cost of electricity represented a large proportion of the cost of lighting, nevertheless, the amount of light provided for each penny spent on lamps had been increased very considerably during the past few decades.

Referring to the paper, Mr. Hughes remarked that all those in the lamp industry had been brought up to appreciate the effect of voltage variation on the life of the lamps, yet the chart shown by the author indicating the effect of varying voltage did not seem to contain any information with regard to its effect on the life. It would be interesting to hear something on that point.

The effect of ambient temperature on efficiency was of great importance in view of the greater tendency to utilise enclosed fittings for these 5 ft. lamps. Whilst it was realised there were only 80 watts in the fitting and the heating effect could not be very great, it seemed there might be some effect on the efficiency by enclosing the lamp completely in a fitting which had a glass front. Some information on that point would also be useful.

Mr. J. N. ALDINGTON, replying to the discussion, thanked the President and Mr. Ruff for their remarks and said that Mr. Ruff was correct in his assumption regarding the method used for determining the surge voltages. That method was used because at the time the tests were carried out he was primarily interested in the magnitude of the voltages which would be impressed on the tube electrodes rather than from the point of view mentioned by Mr. Ruff, viz., the maximum voltage which could be obtained under any conditions, although that was also of considerable interest. The values shown on the slide were not intended to suggest that one switch was preferable to another, but merely to indicate the magnitude of the voltages obtained with particular designs of switch on a particular occasion. Possibly under some conditions voltages of the order of 1,000 to 3,000 volts might occur during the striking surge.

In reply to Dr. Walsh he said that the colour rendering properties of the fluorescent tubular lamp having mixed powders were slightly different from what would be expected from a knowledge of the properties of the individual powders and the proportions in which they were used. He believed that some of the difference was due to the intimate association of the different powders with each other. Some red powders were themselves activated by, and therefore absorbed energy from, the blue powders, and he believed this was the main explanation of the difference between calculated and actual colour rendering properties.

He would not like to venture a prediction in answer to Dr. Walsh's question as to whether it would be immediately possible to produce a fluorescent lamp which would enable the tightening up of the present specification for colour-matching lamps. If powders could be developed which were more efficient—particularly at the deep red end of the spectrum—than those at present available, then what Dr. Walsh had suggested might be achieved, though the prospects were not good under present conditions.

He was grateful to Mr. Ackerley for pointing out the two types of voltage variation. This type of lamp was extremely useful because on a 200- or 250-volt supply the same tube could be used, the difference in voltage being obtained by selecting the appropriate choke tappings. Mr. Ackerley had also asked whether the change in colour during life of these lamps was really due to differences in rate of decline of efficiency of the various fluorescent powders. Of course, if all the powders had an identical rate of fall of luminosity during life there would be no change of colour. In practice it was possible that slight changes in colour during life might occur, but he would not like to say in what direction the change might be for any particular lamp. Differences in manufacture of either the powders or the fluorescent lamps could modify the effect. However, he would say in reply to the next part of Mr. Ackerley's remarks that, due to the low brightness of these sources, slight changes in the apparent colour could take place which had no appreciable effect on the colour rendering properties of the source. If the source brightness was higher such slight differences of colour would be much less apparent. When the paper was published in the TRANSACTIONS Mr. Ackerley would see that it dealt with the point made as to the effect of these low surface brightness sources mounted at low levels. It was preferable to use some diffusing means in view of the large area of the source. As was stated in the published paper, the psychological effect of daylight colour was widely appreciated at the present time in industry; in a large installation there was an amazing benefit as compared with the older light sources.

On the question of choke hum raised by Mr. Raphael and Mr. Ramsay, he said the choke on the 125-volt H.P.M.V. lamp which was operating in the lecture hall was responsible for the noticeable noise, and it was a fact that certain chokes which were suitable for ordinary high-pressure lamps in street-lighting installations were too noisy for some industrial purposes. However, it had been possible to devise and manufacture chokes which had a very low noise level. The solution of putting the chokes in a place remote from the lamps was an admirable one, but it was not really essential because it had been possible to produce noise-free chokes (this was demonstrated).

Mr. Lawson had asked whether it was just chance that the powders used in these fluorescent lamps were responsive to 2537 Å. As a matter of fact all the powders absorbed a range of frequencies. However, due to the fact that the 2537 Å resonance line of mercury could be produced so efficiently, care was taken in the manufacture of the powders to produce those which were most responsive to 2537 Å.

There was a decreasing response to radiation on either side of that value and it had taken some years to develop powders which were extremely efficient by having the peak of their absorption curve at this maximum of 2537 Å.

Replying to Mr. Cunnington's question, he said normally he would not expect there would be any interference by these lamps with delicate telephone apparatus in the vicinity, but that was not authoritative because he had no experience of the type of apparatus referred to.

Power factor correction mentioned by Mr. Baron was an important matter. His own view was that it was correct practice to have the condenser as a separate unit because at any time one would not know for any particular installation whether facilities were available for bulk power factor correction at the end of particular groups of lamps or on the circuits leading from the installation. In many cases individual lamp power factor correction was better, but in other cases the reverse was preferable. As to capacitance controls, units were in course of development, but he did not think they were at present available in this country.

The effect of temperature on starting mentioned by Mr. Dow was certainly an interesting point. It was quite correct that at very low temperatures some difficulty might be experienced in starting, and the object of the warm cloth which had been mentioned was to raise the temperature slightly. This, however, involved another interesting phenomenon, namely, that on stroking the tube, irrespective of any heating effect, there was a tendency to neutralise charges on the walls of the glass, and so to facilitate starting.

Dealing briefly with points raised by other speakers, the author said that the average life for fluorescent tubular lamps was 2,000 hours, which was twice the life of ordinary tungsten filament lamps. Lamp makers were somewhat concerned with the wastage of glass tubing which would be occasioned by throwing away lamps at the end of life and were considering whether any way could be found to avoid this.

The rapid fall off in luminosity during the early part of life was bound up with effects on the surface of the powder caused by the mercury vapour. The whole question was exercising the minds of those responsible for these developments, but it was too early yet to predict to what extent it would be possible to flatten out the maintenance curve. He would, however, point out that the initial efficiency of commercial tubes was in fact higher than was stated in the paper. The value at the end of 2,000 hours was approximately 24 L/W.

The answer to the question about running these lamps in series had to be given in two parts. In the first place he would say that it was certainly possible to run these lamps in series, but since approximately half the mains voltage must be taken up by the choke in order to ensure stable running, it would be appreciated that two 80-watt lamps, each with a running voltage of about 110 volts, could not be stabilised in series on the 200- to 250-volt mains.

In the second place two lamps of lower wattage designed for a lower arc voltage than the present 80-watt lamp could be operated in series with the choke by a comparatively simple circuit arrangement and no difficulty would occur provided the sum of the lamp voltages was correctly related to the mains voltage and choke characteristics. The benefit of such an arrangement, however, was questionable.

Referring to voltage variation mentioned by Mr. Hughes, he gathered that what was meant was the effect of operating the lamp at some voltage other than that for which it was designed. However, as he had pointed out to Mr. Ackerley, that was a position which should not arise because the choke tapping could be changed to suit the voltage. For slight departures from the mean voltage no effect should be noticeable.

As to fittings, provided the designer was aware of the lamp characteristics, and the fact that the optimum efficiency was developed with an ambient temperature at or about 15 deg. C., and provided ventilation was used to reduce excessive temperature rise, excellent results could be obtained with enclosed fittings. This was a case in which the fittings designer and lamp designer must work in the closest possible co-operation.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the List of Members.*

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* In accordance with the present procedure the names of applicants for membership are published in THE TRANSACTIONS as soon as such applications have received the approval of the Council and the subscription for the current year has been duly paid.

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## Changes of Address

A new edition of the List of Members, taking into consideration changes in class of membership, alterations in addresses, etc., and including additions to membership up to the date of publication, is now being prepared. A limited edition will be issued early in the autumn of the present year.

In the meantime, members are requested to notify the Honorary Secretary of recent changes in their addresses, if this has not already been done.

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—"Trans. Illum. Eng. Soc. (London)."*

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# POPULATION DENSITY AND THE HEIGHTS OF BUILDINGS

By H. E. BECKETT, B.Sc. *(Member)*

*(Communicated)*


## SUMMARY

Although it is nowadays generally accepted that, for a given population density, rehousing in higher and more widely spaced buildings is likely to result in improved natural lighting conditions, ideas have hitherto remained somewhat vague.

In the present paper the truth of the above statement, for the special case of tenement blocks arranged in parallel rows, is established by a simple mathematical analysis. It is shown that, except in very open developments such as are rarely encountered in towns, an increase in the height of the buildings will, for a given population density, always improve the lighting conditions; or, less desirably, that more people can by this means be housed on a given site without making the lighting conditions worse. In the latter case it can frequently happen that the increase in population density is accompanied by an *increase* in the amount of open space per person.

The analysis rests on the assumption that, for a given orientation of the blocks, the lighting conditions are defined by the angle of obstruction (determined by its tangent, h/w) at the ground-floor windows. The latter part of the note is concerned with an examination of the amounts of daylight and sunshine which can be received with various values of h/w.


### Introduction.

The relative advantages of high and low tenement blocks, taking all factors into account, have been discussed by numerous authors during recent years, but no definite conclusions appear to have been reached. So far as natural lighting conditions are in question, however, the problem can be treated mathematically and, in the simplest cases, exact solutions obtained. The following analysis holds for rectangular tenement blocks arranged in parallel rows with intersecting streets, as shown in Fig. 1.

### Possible Variations of Population Density for given Lighting Conditions.

The problem, in its essentials, is to define a standard of natural lighting and then, using this standard, to find how the permissible population density varies with the number of storeys in the buildings.

Now, for a given orientation of the blocks, the amounts of skylight and sunshine available at a point near the centre of one of the main façades are determined almost completely by the value of h/w at that point, defined as in Fig. 2. For the present purpose, therefore, it is convenient to specify the required standard of lighting in terms of the value of

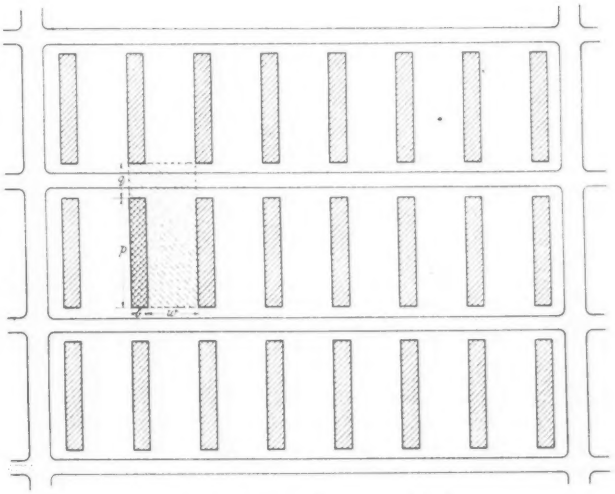

Fig. 1. Layout of tenement blocks.

h/w *at the centre of a ground-floor window*,* thus ensuring that the darkest rooms in the building shall be adequately lit. Ground-floor windows near the ends of a block will obviously enjoy slightly better conditions than a particular value of h/w would indicate, since they receive some extra light from sky visible through the street openings.

Before proceeding further it is necessary to define two new quantities, the "floor-space index," $I_F$, and the "open-space index," $I_O$. The former is the ratio of the total floor area on the site (treating each storey of a building separately) to the total ground area, and is proportional to the permissible population density. The latter represents the proportion of the site area which remains open and which is available for roads, playground space, etc.

The next step is to obtain expressions for these

* In general, h/w varies over the height of a window by an amount depending on the distance of the obstruction from the window. The average value of h/w, at the centre of the window, has therefore been adopted.

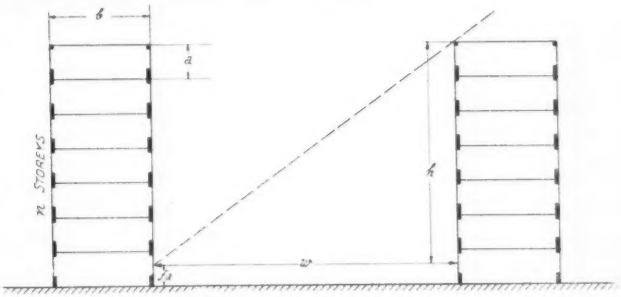


Fig. 2. Section of blocks.

quantities in terms of the dimensions of the blocks and the value of h/w at the centres of the ground-floor windows. For this purpose consider the "unit" of the assumed block distribution, shaded in Fig. 1. The ground area of this unit is $(w+b)(p+q)$. For an n-storey development the total floor area of the unit block is npb. Thus the floor-space index is given by

$$I_F = \frac{npb}{(w+b)(p+q)}$$

or, multiplying top and bottom by h/wb, by

$$I_F = \frac{n.h/w}{h/b+h/w} \cdot \frac{p}{p+q}$$

But from Fig. 2

$$h=(n-f)a.$$

Therefore, finally,

$$I_F = \frac{n.h/w}{(n-f)\ a/b+h/w} \cdot \frac{p}{p+q} \quad \ldots\ldots\ldots\ldots (1)$$

This equation, for given values of h/w, a/b, p/q, and f, i.e., for constant ground-floor lighting conditions, storey section, and block distribution, shows how the floor-space index and, therefore, the population density, varies with n, the number of storeys.

To illustrate this variation, a number of curves are shown in Fig. 3 for the values f=0.6, a/b=1/3, p/q=3, and for various values of h/w.

Examining Fig. 3, it will be seen that in general the quantity $I_F$ increases with n, the curves being steepest for the largest values of h/w, that is, for the closest spacing of blocks. Thus, for any given standard of ground-floor lighting, the greater the number of storeys in the buildings the greater will be the density of population which can be accommodated on the site.

Further examination of Fig. 3 shows, however, that in one instance, for h/w $=\frac{1}{8}$, the reverse effect holds. This can be explained mathematically. Differentiation of the expression for $I_F$, with respect to n, gives

$$\frac{dI_F}{dn} = \frac{(h/w-f.a/b)h/w}{[(n-f)a/b+h/w]^2} \cdot \frac{p}{p+q}$$

Thus, so long as h/w is greater than f.a/b, $I_F$ increases with n. At this value of h/w, $I_F$ is constant; while, for smaller values, $I_F$ *decreases* with increase of n. For the conditions assumed above the critical value of h/w is 0.2, a figure which is unlikely to be reached in any urban development.

Another point that emerges from the expression for the floor-space index, and which can also be seen from Fig. 3, is that, as n increases, the value of the floor-space index tends more and more towards

$$\frac{h/w}{a/b} \cdot \frac{p}{p+q}.$$

It should be noted that the relative advantages possessed in general by the higher buildings are actually somewhat greater than Fig. 3 would suggest. For constant ground-floor lighting conditions the proportion of windows enjoying better conditions is obviously greater in a multi-storeyed block than in one of few storeys. Curves similar to those of Fig. 3, worked out for constant conditions averaged over a façade, would be slightly steeper.

Some time ago Sir Owen Williams stated in the "Weekend Review"* that increasing the number of storeys in blocks of flats could not alter the population density so long as the ground-floor lighting conditions were maintained at a specified standard. It will be obvious from the foregoing analysis that, although this can be true in certain special circumstances, it is far from being true generally.

The fact that Sir Owen Williams based his standard of lighting on the value of h/w at the heads of the ground-floor windows, and not at their centres, does not seriously affect the argument, since the only difference lies in the value of f chosen.

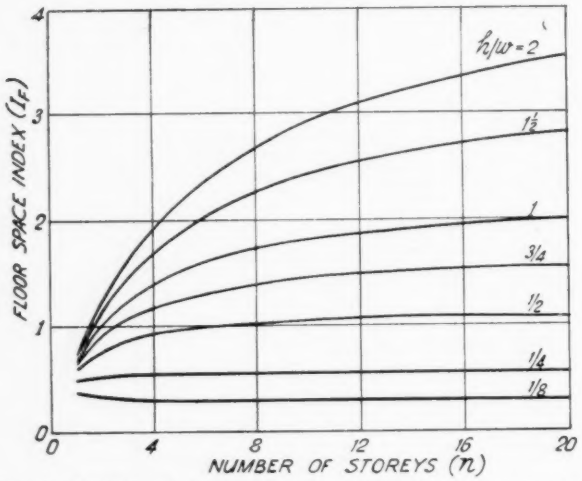


Fig. 3. Variation of floor-space index with number of storeys, for various ground-floor lighting conditions.

### Variations in Amount of Open Space

By similar reasoning to the above an expression can be obtained for the open-space index, in the form

$$I_o = 1 - \frac{h/w}{(n-f)a/b+h/w} \cdot \frac{p}{p+q} \quad \ldots\ldots\ldots\ldots (2)$$

Curves showing the relation between $I_o$ and n for the same conditions as were assumed previously are shown in Fig. 4. In this case, without exception, the proportion of the site area remaining open increases with n.

One other quantity is of interest, the ratio $I_o/I_F$. Since $I_o$ is a measure of the open space and $I_F$ determines the population density, their ratio must be proportional to the amount of open space available per person.

But

$$I_o/I_F = \frac{a/b}{h/w} \cdot \frac{p+q}{p} \cdot \left(1-\frac{f}{n}\right)+\frac{q}{p} \cdot \frac{1}{n} \quad \ldots\ldots\ldots\ldots (3)$$

from which it can be seen that $I_o/I_F$ may increase,

* "Weekend Review," 1933, April 29, p. 470.

remain constant, or decrease with increase of n, according to whether the quantity

$$f\frac{a/b}{h/w}\cdot\frac{p+q}{p}-\frac{q}{p}$$

is greater than, equal to, or less than o.

A typical set of curves for the variation of $I_o/I_F$, derived from those of Figs. 3 and 4, is shown in Fig. 5. In this case constancy of $I_o/I_F$ occurs with $h/w = 0.8$.

### Possible Improvement of Conditions for Given Population Density

So far, attention has been concentrated in showing how the population density, expressed in terms of the floor-space index, can be allowed to increase with

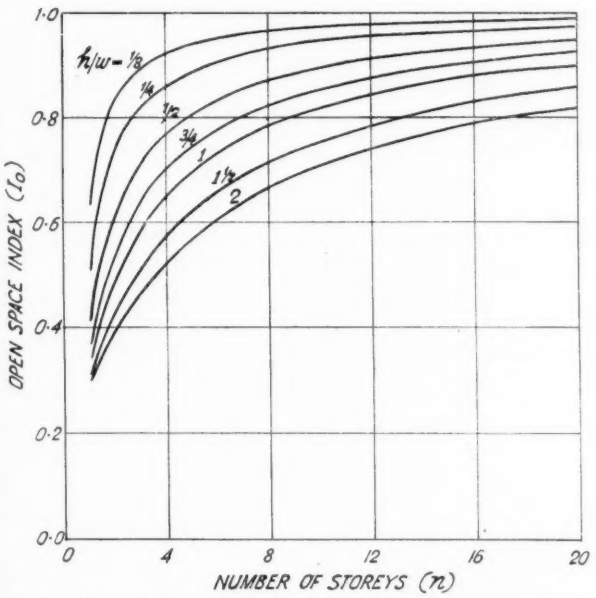


Fig. 4. Variation of open-space index with number of storeys, for various ground-floor lighting conditions.

increase of n, keeping the ground-floor lighting conditions constant; and how, in spite of the larger density, a higher proportion of the site area can remain open.

An alternative, and perhaps a more desirable, way of interpreting the mathematical relations is to find how conditions on the site are improved by the provision of higher buildings, keeping the population density (or $I_F$) constant.

For this purpose the equations may be put in somewhat different form. Equation (1), transposed, becomes

$$h/w = \frac{I_F(n-f)a/b}{n\cdot\frac{p}{p+q}-I_F} \qquad \text{.....(4)}$$

which, for any given value of $I_F$, enables h/w to be plotted against n. Fig. 6 has been obtained in this way, using the same set of conditions as previously,

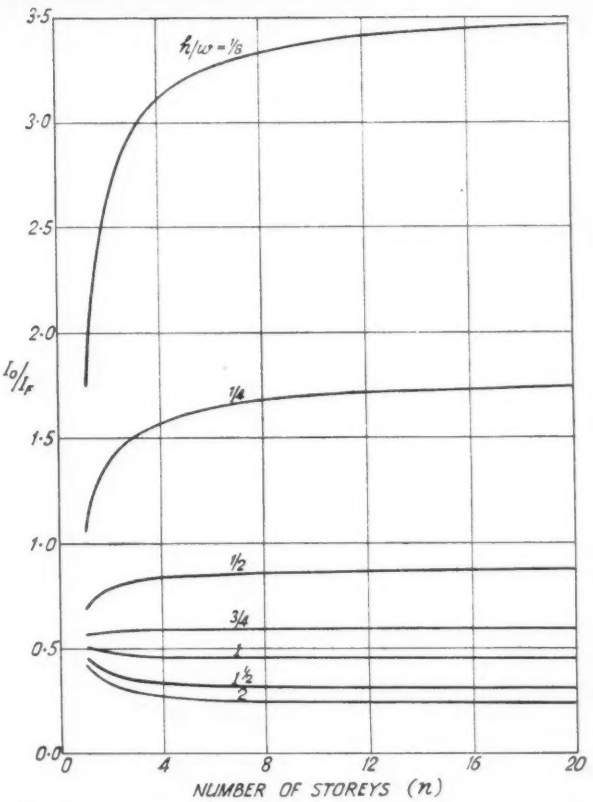


Fig. 5. Variation of $I_o/I_F$ (proportional to open-space per person), with number of storeys, for various ground-floor lighting conditions.

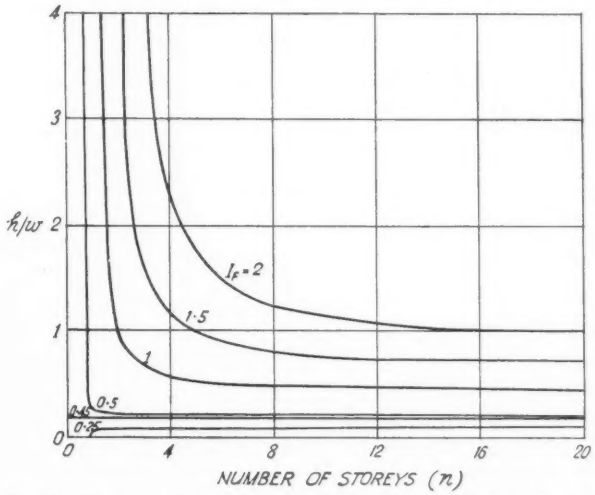


Fig. 6. Variation of ground-floor lighting conditions with number of storeys, for various values of the floor-space index.

and the curves show clearly that, in general, h/w decreases as n increases, that is, that the ground-floor lighting conditions improve as the buildings are made

higher, keeping the amount of accommodation constant. The improvement is most rapid for small values of n.

Again, as in Fig. 3, the general rule is not followed under all conditions. At the value $I_F = f.\frac{p}{p+q}$, h/w is independent of n, and for smaller values of $I_F$ h/w increases with increase of n. In the present instance this is not of much consequence, for the critical value of $I_F$ is 0.45, which is outside the ordinary range of urban conditions.

It only remains to find how the open-space index ($I_o$) varies with n when the population density is constant. The required equation is simply

$$I_o = 1 - \frac{I_F}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Thus, for a given value of $I_F$, the proportion of open space must always increase with increase of n. Specimen curves for different values of $I_F$ are shown in Fig. 7.

### Typical Analysis.

As an example of the use of the above formulae the following practical problem is worked out in some detail.

On pages 91 and 94 of the First Report of the Council for Research on Housing Construction* are shown specimen plans of a block of flats comprising three 3-bedroom flats and three 4-bedroom flats on each floor. The following data have been obtained from these plans:—

| | |
|---|---|
| Average floor area per flat (including walls and staircase space) | ... 702 sq. ft. |
| Length of block (p) | ..... 166 ft. |
| Assumed road openings (q) | ... 50 ft. |
| Storey height (a) | ..... 8 ft. 7½ in. |
| Width of block (b) | ..... 25 ft. 3 in. |
| Height of centres of ground-floor windows as ratio of storey height (f) | ..... 0.58 |

Using these values the number of flats allowable per acre and the amount of open space available per flat may be calculated for any desired values of n and h/w. Thus, for five-storey and ten-storey blocks, spaced to give a value h/w = 3/4 at the centres of the ground-floor windows, the following figures have been obtained:—

TABLE I.

| Number of Storeys (n) | Floor-space Index ($I_F$) | Number of Flats per acre | Open-space Index ($I_o$) | Open Space per Flat (sq. yd.) |
|---|---|---|---|---|
| 5 | 1.27 | 79 | 0.74 | 45.4 |
| 10 | 1.45 | 90 | 0.85 | 45.8 |

For the prescribed ground-floor conditions an increase in the number of storeys from five to ten gives an increase of about 12½ per cent. in the number of flats per acre, with a slight increase in the amount of open space available per flat.

As a further matter of interest Table II. has been prepared, showing the values of h/w obtainable and the proportion of open space on the site for various numbers of flat per acre, constructed in five-storey and ten-storey blocks.

TABLE II.

| Number of Flats per acre | Floor-Space Index ($I_F$) | h/w | | Open-Space Index ($I_o$) | | Open Space per Flat (sq. yd.) | |
|---|---|---|---|---|---|---|---|
| | | n=5 | n=10 | n=5 | n=10 | n=5 | n=10 |
| 10 | 0.16 | 0.066 | 0.069 | 0.97 | 0.98 | 469 | 476 |
| 20 | 0.32 | 0.138 | 0.140 | 0.94 | 0.97 | 227 | 234 |
| 30 | 0.48 | 0.22 | 0.22 | 0.90 | 0.95 | 146 | 154 |
| 40 | 0.64 | 0.30 | 0.29 | 0.87 | 0.94 | 106 | 113 |
| 50 | 0.80 | 0.40 | 0.38 | 0.84 | 0.92 | 81.3 | 88.8 |
| 60 | 0.96 | 0.50 | 0.46 | 0.81 | 0.90 | 65.2 | 72.9 |
| 70 | 1.12 | 0.62 | 0.55 | 0.78 | 0.89 | 53.8 | 61.4 |
| 80 | 1.28 | 0.76 | 0.65 | 0.74 | 0.87 | 45.1 | 52.8 |
| 90 | 1.44 | 0.91 | 0.74 | 0.71 | 0.86 | 38.3 | 46.1 |
| 100 | 1.60 | 1.08 | 0.85 | 0.68 | 0.84 | 32.9 | 40.7 |
| 120 | 1.92 | 1.52 | 1.08 | 0.62 | 0.81 | 24.9 | 32.6 |

This table brings out very clearly the fact that, in densely populated areas, substantial improvements both in natural lighting conditions and in the proportion of ground space left open can result from a substitution of ten-storey blocks for five-storey blocks.

In two cases only, for the very low densities of ten and twenty flats per acre, does an increase in the number of storeys result in a higher value of h/w.

### Amounts of Sunshine Available.

Although the quantity h/w has been used as a convenient index of natural lighting conditions, no information has yet been given as to the amounts of

* "Slum Clearance and Rehousing." First Report of the Council for Research on Housing Construction. (P. S. King and Son, Ltd., London, 1934.)

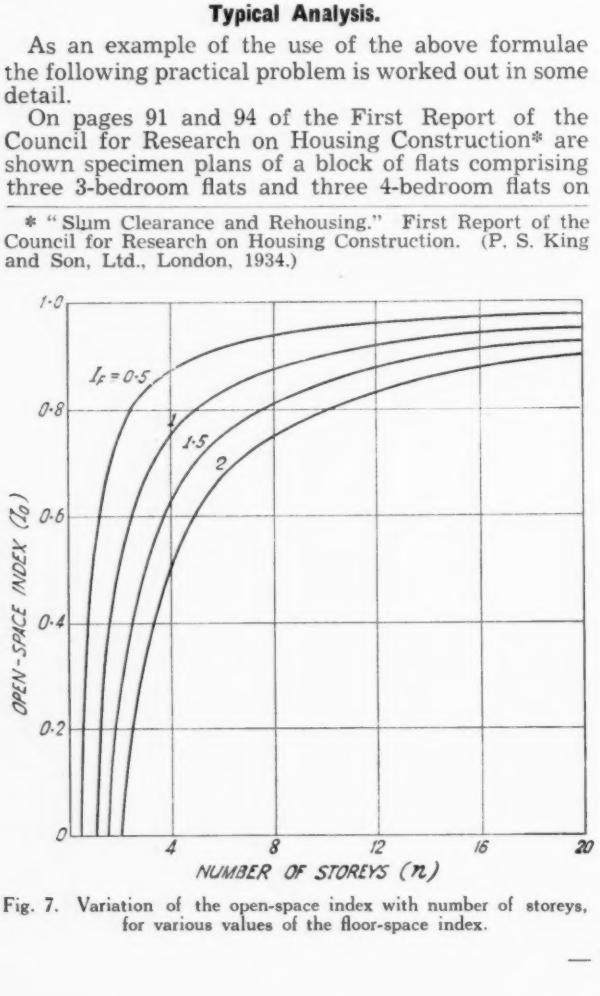


Fig. 7. Variation of the open-space index with number of storeys, for various values of the floor-space index.

daylight and sunshine receivable with various values of h/w.

For sunshine, the necessary data have already been set out very fully in Appendix J of the Report on the Orientation of Buildings, issued by the Royal Institute of British Architects in 1933. The following table of figures, showing the amounts of sunshine receivable on a straight façade, at midwinter, for various aspects of the façade and various degrees of obstruction, has been extracted from that Appendix.

TABLE III.

| h/w | ¼ | ½ | ¾ | 1 | 2 |
|---|---|---|---|---|---|
| Aspect of Façade | Period of Insolation (hours) | | | | |
| N. | — | — | — | — | — |
| N.N.E. : N.N.W. | — | — | — | — | — |
| N.E. : N.W. | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 |
| E.N.E. : W.N.W. | 1.4 | 1.1 | 0.8 | 0.7 | 0.4 |
| E. : W. | 2.4 | 1.7 | 1.2 | 0.9 | 0.5 |
| E.S.E. : W.S.W. | 3.5 | 2.2 | 1.5 | 1.1 | 0.5 |
| S.E. : S.W | 4.7 | 2.1 | 0.9 | 0.6 | 0.2 |
| S.S.E. : S.S.W. | 3.5 | — | — | — | — |
| S. | 1.6 | — | — | — | — |

It will be seen that, so long as the aspect of the façade is east or west, or within 22½° of these directions—that is, in the present case, so long as the axes of the blocks do not deviate by more than 22½° from the north-south direction—appreciable amounts of sunshine are receivable at midwinter with comparatively high values of h/w. Thus for h/w=3/4, façades facing east-north-east, east, and east-south-east can receive, respectively, 0.8 hr., 1.2 hr. and 1.5 hr. of sunshine. It should be noted that façades facing in northerly and southerly directions are, except for very low values of h/w, equally sunless at midwinter.

On this evidence it would not be unreasonable to demand that, in blocks of flats arranged as in Fig. 1, at least one hour of sunshine should be receivable on midwinter's day at the centres of all ground-floor windows. In the most favourable orientation of the blocks, with the axes running north and south, this would require a value of h/w of approximately 0.9. Deviations of the axes from this direction would necessitate somewhat lower values of h/w.

Where it is not considered important that both façades of a block should be sunny then a higher standard than the above can be demanded on the sunnier façade.

## Daylight Received in Typical Ground-Floor Living Room.

In considering the amounts of daylight—or, more strictly, skylight—which are available, the most convenient method of approach is to determine what proportion of a horizontal plane within a room is able to receive light directly from the sky. As explained in Illumination Research Technical Paper No. 7,* if a line is drawn on such a plane, dividing the area which receives direct skylight from that which does not, then, except where the skyline of the obstructing row of buildings is very irregular, this "no-sky" contour can be taken as defining very closely the adequately lit portion of the room.

This procedure has been followed in the case of a ground-floor living room of the flats to which the previous analysis has been applied. The internal measurements of the room are 15 ft. by 11 ft. 3 in. by 8 ft. A rectangular window opening, 5 ft. wide by 4 ft. high, has been assumed, and "no-sky" contours have been plotted on a horizontal plane at sill level.†

The results for uniform obstructions giving various values of h/w *at the window-head* are shown in Fig. 8.

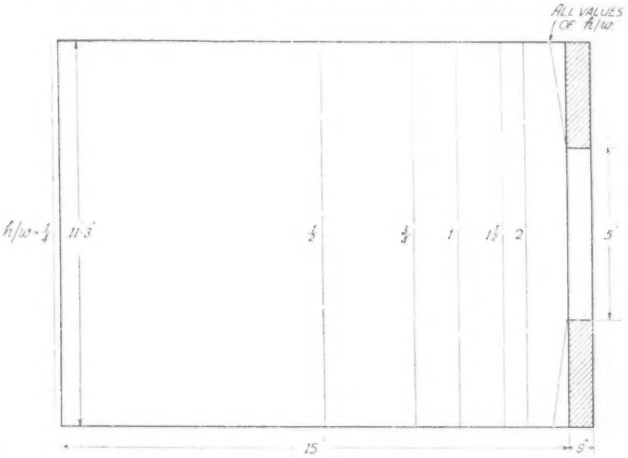


Fig. 8. "No-sky" contours for ground-floor living room.

For this purpose it is impossible to work in terms of the value of h/w at the *centre* of the window opening without postulating the height and spacing of the obstructing buildings. For multi-storeyed blocks, however, there should not be very much variation in h/w over the height of a ground-floor window.

The areas of the room receiving direct skylight, expressed as percentages of the total room area, are given in Table IV.

TABLE IV.

| h/w | ⅛ | ¼ | ½ | ¾ | 1 | 1½ | 2 |
|---|---|---|---|---|---|---|---|
| Percentage Area Receiving Skylight | 99.1 | 99.2 | 47.3 | 29.8 | 20.7 | 11.9 | 7.3 |

As yet, no one has ventured to specify what proportion of a living room should receive direct skylight. It is suggested tentatively that some figure near 30 per cent. might reasonably be adopted as a minimum standard.

This would require much the same value of h/w as would give the suggested one hour of sunshine at

* Illumination Research Technical Paper No. 7, "Penetration of Daylight and Sunlight into Buildings," p. 14 et seq.

† With uniform obstructions, such as are assumed, the positions of the no-sky contours are affected markedly by changes in the height of a window but not by changes in window width. The latter influence the total amount of light entering the room, and particularly the amount of light reflected from the walls to the back of the room.

all ground-floor windows, for favourable orientations of the blocks.

### Effect of Balconies.

In conclusion, it should be noted that the whole of the foregoing analysis applies to tenement blocks with internal staircases, and *without external balconies*. From the lighting aspect balconies must be regarded as serious obstructions. The trouble lies not so much in the loss of sunshine—for, in winter, when sunshine is most welcome within a room, the sun is at a sufficiently low angle for its rays to reach the windows beneath the balconies—but rather in the loss of daylight. A balcony, for the window beneath it, obstructs just that part of the sky which is most valuable for lighting purposes. Wherever possible, therefore, living rooms should not be obstructed in this way.

The above analysis is part of an investigation carried out some years ago by the author, with the concurrence of the Department of Scientific and Industrial Research, for the Council for Research on Housing Construction, to whom acknowledgment is now made.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the List of Members.*

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Williams, J. M. ... 109, Aurelia Road, Croydon, SURREY.

* In accordance with the present procedure the names of applicants for membership are published in THE TRANSACTIONS as soon as such applications have received the approval of the Council and the subscription for the current year has been duly paid.

## Changes of Address

A new edition of the List of Members, taking into consideration changes in class of membership, alterations in addresses, etc., and including additions to membership up to the date of publication, is now being prepared. A limited edition will be issued early in the autumn of the present year.

In the meantime, members are requested to notify the Honorary Secretary of recent changes in their addresses, if this has not already been done.

### The Library.

It will be recalled that the original list of books in the Library appeared in THE TRANSACTIONS for April, 1939, pp. 53-57, and that certain additions have since been recorded (see THE TRANSACTIONS, June, 1940, p. 74; July, 1940, p. 88).

The following further additions have since been made:—

| SECTION No. | TITLE. | AUTHOR. | DATE. |
|---|---|---|---|
| 1 | The Heating, Ventilation, and Lighting of School Buildings | Seymour, W. D. ..... | 1939 |
| 1 | Practical Electric Illumination and Signal Wiring Methods | Croft, T. ... ..... | 1939 |
| 1 | The Application of Arc Lamps to Practical Purposes ..... | Eck, J. ..... | 1910 |
| 1 | The Electric Light in our Homes ..... | Hammond, R. ..... | 1884 |
| 12 | Photo-Electric and Selenium Cells ..... | Fielding, T. J..... | 1940 |
| 13 | Textbook of Light ... | Stewart, R. W., and Satterly, J. ..... | 1941 |
| 19 | Report on the Gas Industry in Great Britain ..... | ..... | 1939 |

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."*

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# LIGHTING IN THE WOOLLEN AND WORSTED INDUSTRY

By T. C. HOLDSWORTH, A.M.I.E.E. *(Fellow)*, J. W. HOWELL, D.L.C., A.M.I.E.E. *(Fellow)*, and J. H. JACKSON, B.Sc., A.M.I. Mech.E. *(Member)*

*(Paper read before the Leeds (North Midland) Centre on May 4th, 1942.)*

In normal times the textile industry as a whole in this country employs approximately 1,000,000 operatives, of whom rather more than one-fifth were employed in the woollen and worsted section. In view of the magnitude of the industry it is perhaps surprising that only recently an attempt has been made to include in the I.E.S. Code illumination values for textile processes. The delay in determining these values has been due apparently to the complexity of the industry, a complexity which will be realised when one considers the wide variety of the finished product.

At the outset of the paper it will be as well to make clear the meaning of the terms " woollen " and " worsted." Worsted yarn is one in which all the fibres are kept parallel to one another. The arrangement of the fibres within the thread constitutes the essential difference between the two sections of the wool industry. There are other differences, for example, in the worsted section short fibres are deliberately eliminated and it is also unusual for any attempt to be made to use reclaimed wool. Typical worsted yarn is made from 100 per cent. virgin wool.

The production of worsted yarn is a comparatively complex process, involving eighteen to twenty-four separate operations between the wool washing and the production of the thread in its final form. The woollen industry, producing a thread from material which is on the whole shorter, is in a position to use reclaimed wool, and it is probable that in the woollen blend over 50 per cent. of the material is shoddy or mungo. The shoddy and mungo are vital parts of the raw material supplied to the woollen industry by the rag trade.

Once the wool has been converted into either woollen or worsted yarn the distinction between the two sides of the industry becomes less noticeable, and no definite line of demarcation can be made between weaving and finishing plants employing the two types of wool thread, but speaking generally worsted weaving tends to be finer, and at the finishing end of the industry efforts are made to preserve in the finished product the identity of each individual thread. A typical worsted fabric shows clearly the weave structure, and is free from any appearance of a fibrous or hairy surface. On the other hand, in a typical woollen fabric, individual threads become matted together during the finishing process and the surface acquires some fibrous cover which is shown in an extreme case in blankets which have pronounced pile.

It is proposed to give a very brief outline of the various processes involved, but one real difficulty the lighting engineer faces is that the processes in different districts vary considerably. It is possible to give a typical flow chart (Fig. 1) which, however, is not invariably followed by all manufacturers. It will be realised that wool staples may vary in length from 24 in. down to less than 1 in. in length, and wide variations such as those in the raw material inevitably involve changes in both the routine of yarn manufacture and the finished product.

Having transformed the raw material into yarn the next job is to prepare it for the loom. Cloth is formed, of course, from the intersection of warp ends with the weft in the shuttle. The yarn is transferred into warp forms in the warping or weaving department, and usually on either balloon warping mules or on some type of Yorkshire dressing frame. The yarn that is required for weft can be taken straight from the spinning department without any further

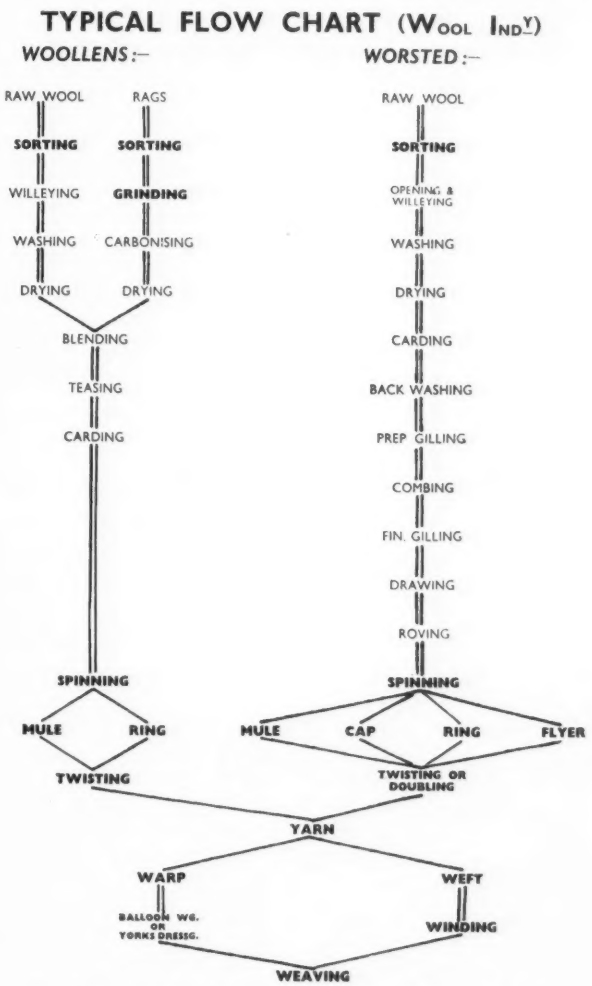


Fig. 1. Typical flow chart for the Woollen and Worsted Industry.

Operations in ordinary type require little visual effort.
Operations in thick type require special treatment.

rewinding. If, however, automatic looms are used, that is in which the shuttles are replenished automatically, it is generally necessary to rewind the weft on to suitable wood bobbins or paper tubes. This takes place in the winding department.

From the winding and warping department the material moves forward to the looms, and there is generally no fundamental difference between the looms used on the woollen and worsted sides of the industry. After weaving, the cloth is normally

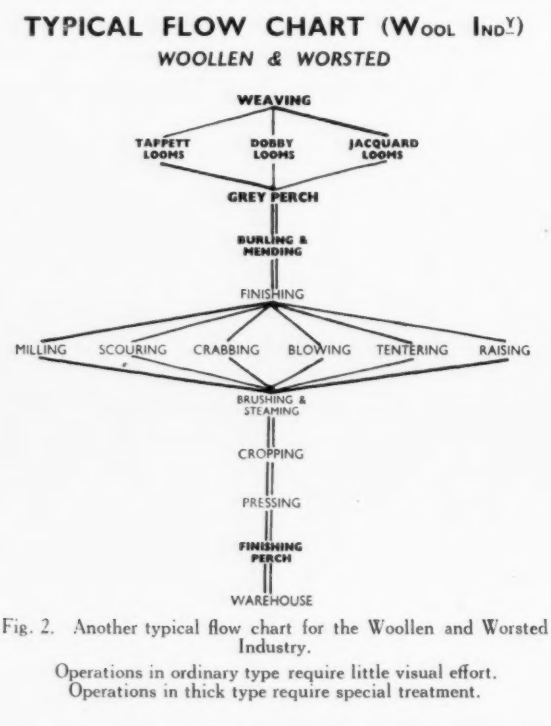


Fig. 2. Another typical flow chart for the Woollen and Worsted Industry.

Operations in ordinary type require little visual effort.
Operations in thick type require special treatment.

inspected, called in the trade "grey perching," obvious defects are mended by hand and in some cases knots are pushed through on to the back of the piece and foreign matter such as straw removed. The cloth then passes to the finishing department.

A further typical flow chart is given in Fig. 2.

## LIGHTING REQUIREMENTS.

### Values of Illumination Levels.

A careful analysis of the operations showed that a number of the operations could only be classified as rough processes, that is to say processes in which no exacting visual task was present. In fact, in many "touch" plays a much more prominent part than "vision," whilst in others the processes are mainly mechanical and automatic requiring lighting which can only be classified as "safety" lighting. Thus it is felt that the processes on the flow chart in ordinary type should be included in the 6 to 10 ft.c. range, and can be served efficiently by a general overhead system planned to give even distribution throughout the area of the floors.

The remaining manufacturing processes require much more careful treatment, as apart from the level of illumination such properties as thread discrimination where shadows are of importance, shadow elimination, colour matching and so on become involved. Under this section, however, only levels of illumination will be given, whilst in subsequent sections special requirements will be considered. It should be borne in mind that the values are those to be given on the actual operations which may be on a vertical, horizontal or, in fact, any plane.

(a) Processes which require medium visual perception (10 to 15 ft.c. range).

| *Woollen.* | *Worsteds.* |
|---|---|
| Rag sorting. | Sorting. |
| Rag grinding. | Combing (coloured). |
| Mule spinning. | Mule spinning. |
| Frame spinning. | Frame spinning. |
| Winding. | Twisting (doubling). |
| Cropping. | Winding. |
| Weaving (heavy woollens). | Cropping. |

(b) Processes which require prolonged visual perception (range 15 to 25 ft.c.).

| *Woollen.* | *Worsteds.* |
|---|---|
| Warping (including Balloon warping and warp dressing). | Warping (including Balloon warping and warp dressing. |
| Weaving (fine woollens). | Weaving. |
| Designing. | Designing. |

(c) Processes which require severe visual perception (range 25 to 50 ft.c.).

| *Woollen.* | *Worsteds.* |
|---|---|
| Burling. | Weaving (fine worsteds. |
| Mending. | Burling. |
| | Mending. |

(d) Precision processes (range above 50 ft.c.).

| *Woollen.* | *Worsteds.* |
|---|---|
| Perching. | Perching. |

There are certain other processes, such as "healding" (drawing-in), condenser end of woollen cards and Laboratories which require special treatment usually of a comparatively low order of general lighting, plus local lighting on the actual operation.

As has already been indicated the majority of processes, including all those shown in ordinary type on the flow chart, can be adequately illuminated by using standard dispersive reflectors, and apart from special cases, such as steamy or vaporous atmospheres or where colour correction is necessary, there appears to be no warrant, in the main, for elaborate and costly fittings. In certain sections, however, particularly in carding, where the atmosphere is often laden with fine wool fibres or "fly" maintenance, can be greatly simplified by the provision of clear glass visors on the face of the fittings. To give some idea of the processes involving special requirements

some short description will be necessary and, where possible, typical illustrations are shown.

### Dyeing

The dyeing process is not one where special lighting or colour correction is necessary, as all colour matching is in general performed outside the dyehouse in the colour matcher's office. An exception with regard to special lighting may occur where vats are hooded for steam economy. In such cases a vapour proof fitting is of value to the operator. Steam is always present to a greater or lesser degree and the cloud may be very dense. A high roof in a dyehouse allows for the dispersal of the steam, but existing buildings are not likely to be altered even where possible, owing to the economic position. Lighting schemes should, therefore, make due allowance for steam and light penetration if a permanent vaporous atmosphere is necessary. In the worsted industry dyeing takes place after combing. The levels of illumination are as follows:—

| | |
|---|---|
| Colour matching (corrected to approaching N. Daylight) | 50-10 |
| Printing, including machines with speeds up to 30 ft. per min. | 15-25 |
| Dyeing (all forms) | 6-10 |

### Wool Grading and Sorting

Wool is generally received either in bales already cleaned or in the form of fleeces which have to be sorted and graded.

The opening and sorting room of a woollen mill necessitates care since various classes and natures of wool are received and sorted according to their grade. This involves also colour discrimination, since different shades and qualities of wool are present, and careful sorting is necessary.

The room is generally arranged with benches or sorting tables running round the walls, the centre of the room being taken up with either bales of wool or skeps. It is necessary to use light which is constant in colour and approximates to daylight over the benches, and in some cases this has been attained by the use of tungsten lighting with daylight visors, whilst the introduction of the fluorescent tube has provided another possible solution. The remainder of the room can very well be illuminated by general lighting of medium value, since apart from the weighing machines little work is carried out, apart from moving the bales as required.

Fig. 3. A Sorting Room with general overhead lighting, supplemented by stronger illumination from dispersive units, equipped with colour-correcting visors and mounted at a lower level.

### Carding

Woollen carding plants are usually large and take up a great deal of floor space, the material going in the automatic hopper at one end in the form of

Fig. 4. Carding plants are really a series of machines built into a single unit. Considerable quantities of "fly" are always present even when the hoppers are covered. Note the accumulation on fittings, belts and machines although the shed had only just been cleaned down for these photographs. One illustration shows the hoppers open and the other closed.

opened and blended wool and coming out at the condenser end as "thread" wound on to condenser bobbins. Owing to the height of the machines it is sometimes impracticable to illuminate the top horizontal surface, particularly as most rooms are low and headroom consequently limited. From a safety point of view lighting is required on the vertical sides of the machines where the driving gear is situated. As lighting placed over the cards would invariably create heavy shadows on the sides it is usually spaced so that the units are mounted in the gangways. At the delivery end (the condenser end) it is necessary to provide local lighting as shown in the accompanying illustration.

### Combing

Combing peculiar to the manufacture of worsted yarn is usually done in a section of the floor and is often done by circular combs, the object of which is to remove short fibres commonly known as "noils" from the wool, and at the same time to ensure "sliver" in which the fibres are parallel to one another. In the main the wool is white with a high re-

flection factor, and where this is the case the visual task is not exacting. The processes are automatic, and should a break occur at the delivery end of the machine a stoppage immediately takes place. Incidentally, the sliver delivered from the machine is

Fig. 4a. Another view of Carding Plant, showing the hoppers open.

about 2 in. thick. In certain cases coloured combing may take place and higher values should then be used to compensate for the lowered reflection factor.

### Mule Spinning

The condenser bobbins from the carding machines are taken to the mules where the actual spinning of the thread takes place.

The whole of the space from the delivery rollers to the position occupied by the carriage in its most outward position must be evenly illuminated. It will be realised that the mule carriage traverses backwards and forwards over a distance of 7 ft. The machine itself may be about 80 ft. long. The mules

Fig. 5. Combing. A well-planned system of general lighting ensures sufficient illumination on the circular combs seen at the right side of the illustration.

thus take up a considerable amount of floor space which requires general illumination. A spinner should be able to keep all the threads under observation. The illustration shows a modern system of fluorescent lighting.

### Frame Spinning

Whilst mule spinning is usual in the woollen industry, in the worsted trade mule, ring, flyer and cap spinning are all employed. From the lighting engineer's point of view, ring, flyer and cap spinning are all very similar to one another, and can be grouped together in a general title of "Frame Spinning." Frame spinning provides an entirely different set of lighting conditions, this type of frame being

Fig. 6. Mule Spinning. An excellent system of fluorescent tube lighting very recently installed in a local mill.

adopted generally, an obvious advantage being its conservation of floor space.

It is generally considered expedient to arrange the lighting units in rows down the gates between adjacent frames which normally face one another. The operative must be able to see the thread clearly from the point where it leaves the bobbin through the delivery rollers right down to the actual spinning spindle.

The principal areas which require illumination are (1) a vertical plane about a foot wide running the whole length of the frame about 2 ft from the floor; (2) an inclined plane of threads about 3 ft. 6 in. from the floor; and (3) a vertical plane about 4 ft. 6 in. from the floor running the whole length of the frame.

The material after spinning is in the form of a single thread, and, as such, may be suitable for some purposes, for example, much of the weft used is in the form of singles yarn. For many other purposes, however, two- or three-fold yarn may be required, and for this purpose the twisting or doubling frame is used. The lighting requirements of these twisting frames are substantially the same as spinning frames.

### Warping Department.

After the yarn leaves the spinning department either in a single or two-fold form, it proceeds to

either the warping department or to be put on beams ready for the loom, or to the winding department to be prepared as weft. The yarn on bobbins or in cop form is placed in a creel having a capacity of 100 to 200 ends. These are drawn through a leasing reed, then through the reed on the traversing head, and so on to the balloon where the warp is built up one section at a time. A section may vary in width from 1 in. to 10 in. or so, depending on the repeat, if any, of the pattern. The number of sections is obviously determined by the width of the sections and the width of beam.

The warper must be able to see that all the ends are intact and that they are all in the correct order. The speed of the yarn is comparatively high, and a figure of 15 to 25 ft.c. has been suggested for this process.

### Healding or Drawing In.

The process of healding consists of threading each individual end through the correct mail eye in the heald shafts or gears. As there may be up to thirty-six of these frames all threaded with heald wires (each heald wire having an eye in the centre) it will be realised that it is a process requiring most careful lighting. The light must penetrate through the gears or heald shafts so that when the drawing-in hook is inserted by the operator the correct particular mail eye can be seen and distinguished from the remainder.

It is customary for the "drawer-in" to sit in front of the healds as shown, and a girl to be at the back. The "drawer-in" pushes his hook through the appropriate heald and the girl from the other side attaches the thread which is then drawn through. General lighting in itself is not sufficient, many experiments having been unsuccessful. It would appear, therefore, that the only solution can be one where general lighting is supplemented by the use of a small concentrated reflector which directs light on to an area not more than 1 ft. diameter. In view of the presence of an operator the other side of the work, the surface of the light source should not exceed a brightness of two candles per sq. in.

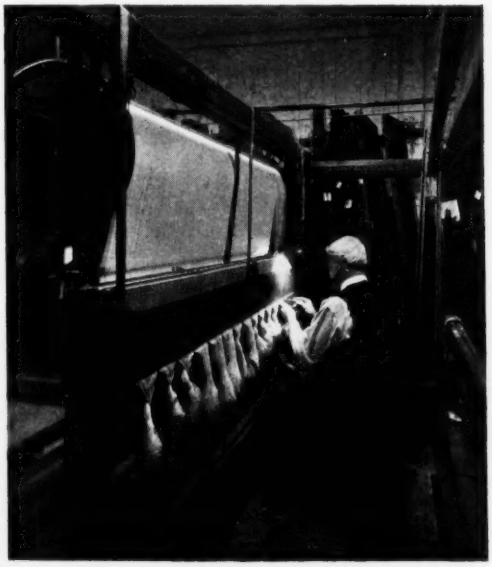

Fig. 7. A good example of local lighting, the light being entirely shielded from the worker's eyes.

### Weaving.

There are so many kinds of looms and so many different types of fabrics that it is impossible to give one figure for the intensity of illumination that can be generally considered satisfactory. It is suggested dividing them into three classes:—

| | |
|---|---|
| Heavy woollens | 10-15 ft.c. |
| Fine woollens and medium worsteds | 15-25 ft.c. |
| Fine worsteds | 25-50 ft.c. |

The number of warp ends may vary from 10 to more than 100 per inch and the number of weft threads or picks per inch shows a correspondingly wide variation. Speaking generally, in the heavy woollen district centred round Dewsbury and Morley, the threads are coarser in count, that is, thicker in diameter, and there are fewer per inch, whereas in the fine worsted trade centred round Huddersfield, threads are finer and the number of ends per inch greater.

The lighting engineer, however, has not merely to decide into which category to place the looms with respect to the desired level of illumination, he has also to consider the obstruction caused by shafting and belts. Good general lighting is usually preferred, but due to the presence of overhead obstructions of one sort or another, localised general lighting is often necessary. The looms themselves may offer considerable obstruction. They can be classified into three main types:—

(a) Tappet looms capable of weaving only the simplest fabrics in which overhead obstruction on the looms themselves may be negligible or entirely absent.

(b) Dobby looms suitable for the weaving of simple geometrical patterns in which the number of shafts may be up to thirty-six or so. The dobbies in these looms and the rails on which they are mounted generally present some obstruction.

(c) Jacquard looms—these are suitable for weaving complicated geometrical patterns or even floral patterns, and the jacquard itself always presents a considerable obstacle to general lighting. The jacquard cards which control the design may be over the weaver's head, at the back, or drawn to one side, and the pack of cards in some sections of the trade is very bulky.

If the loom is an automatic one, that is to say, a loom in which the weft supply is replenished automatically, the illumination on the shuttle boxes is not so important as in the non-automatic type where the weaver must be able to see the shuttle in its box so that the weft can be replenished as required.

We must also note that in box looms (which may have up to four or six shuttles each with its own dif-

ferent kind of weft) the need for adequately lighting the shuttle boxes becomes still more important.

In the past a considerable number of obsolete conical shades have been used as local lighting units, and it is still by no means uncommon to find weaving sheds in which the conical reflectors are practically touching the shuttle boxes. Local intensities of 100 to 200 ft.c. can be found in such cases. It is, therefore not surprising that general lighting schemes of comparatively low intensity have not always been popular with the weavers.

Apart from attention to replenishing the weft, the weavers' main job is to see that there are no obvious defects in the cloth that is being woven and to watch for the appearance of broken warp threads or clumsy knots which, if woven into the cloth, may constitute a fault.

Warp ends often break in the heald shafts or immediately between the back of the reed and the front of the heald shafts. This is obviously due, firstly, to the tension imposed on the warp ends as the shafts move up and down to form the "shed" or space for the shuttle, and, secondly, to the rubbing motion that takes place. Just as in healding or drawing-in the operative must obtain a clear view through heald shafts, so a weaver who has to repair broken warp threads must be able to see clearly through the healds. Whilst most of the weavers' time is normally spent at the front of the loom, it must not be inferred that we can neglect the lighting at the back. A suitably placed fitting at the back of the loom is of considerable assistance to an operator who, though working at the front, endeavours to see through the mass of heald wires or cords.

Figure 8 shows a typical weaving shed where automatic looms have been illuminated by a general system using industrial diffusing units to give 20 to 25 ft.c. This is an exceptional case where head room lay out, and individual drives have all contributed to easy planning. Whilst good results undoubtedly were attained and production materially improved,

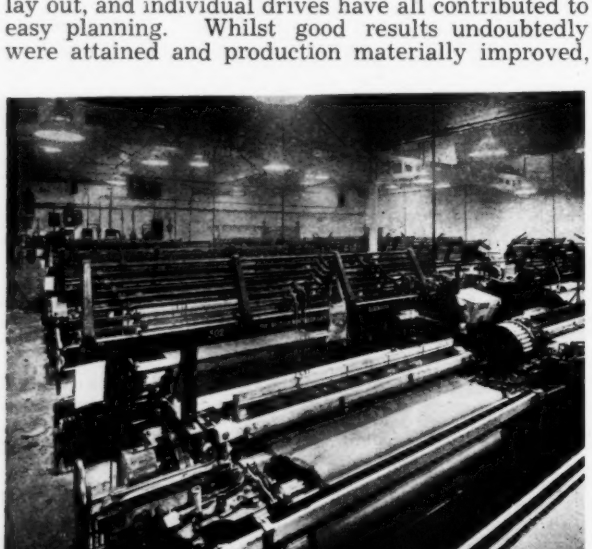

Fig. 8. General Lighting by Industrial Diffusing Reflectors.

it is doubtful whether a case can be substantiated for a costly system of this kind. Equally good results might have been attained by simpler means.

Figure 9 is given to show the deep shadow which may occur behind the sley. This particular example is actually taken where, by use of diffusing units,

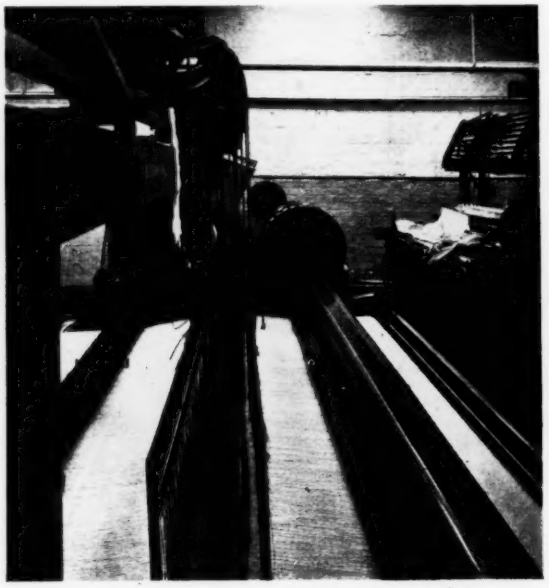

Fig. 9. Heald frames lighted by a general system of industrial diffusing units. Note how clearly the threads stand out, but also the persistent heavy shadow behind the "going part."

shadows have been somewhat softened, but it still remains a problem. The weaver's desire for high local intensities can also be seen in the use of local lighting units over the central portion of the "going part." The "going part" carries the reed which serves to separate and evenly space the warp threads, and as the "going part" reciprocates, serves also to beat the weft into position. The sley or reed is supported at the bottom by the "going part" and at the top by what is known as the reed cap or hand rail. This reed cap is often the cause of troublesome shadows which may be worse in an ill-considered scheme of general lighting than in a comparatively crude scheme of local lighting.

The results obtained by using fluorescent tubes on loom lighting have been most satisfactory, though as yet there appears to be no general agreement about the best arrangement. In some cases, tubes mounted parallel to the warp are preferred, whilst in others preference is shown for tubes parallel to the weft. The determining factor is usually the obstructions present due to the drive and the construction of the loom. If two looms of medium width are placed face to face two tubes placed warp-ways (each in line with one of the loom frame sides) satisfactory results are obtained at the front of the loom; light coming from both sides makes it impossible for a weaver to throw

anything except a very soft shadow on to the cloth. If in addition to those two units the warps at the back of the loom are served by a tube placed weftways and mounted so that the light is directed somewhat towards the back of the heald shafts, the light

Fig. 10. A recent installation of fluorescent tubes in a large productive plant. On the left of the illustration are shown Dobby Looms and on the right Jacquards.

penetration can be most helpful to a weaver who has to pick up a broken end.

### Jacquard Looms.

The same conditions relative to the healds as for other looms obtain with the added handicap that the cordage extend to overhead equipment, and the conditions are further complicated by "cards" which may be 2 or 3 ft. wide and form a barrier to the passage of light, especially as when the loom is operating they are constantly in motion. Thus the size of the loom and the volume of card gear and harness overhead provide light problems peculiar to this class of loom. The simpler form of jacquard such as shown on the right in Fig. 10, can be illuminated in much the same manner as dobby looms, with the exception that the units must be mounted sufficiently below the card gear to prevent the obstruction of light.

Whilst the illustration Fig. 11 is not in a productive plant and consequently conditions are not identical, nevertheless excellent conditions have been obtained by using fluorescent tubes, one at the front and one between each pair of loom backs. The Halifax Technical College is to be congratulated on installing in its Textile Section modern lighting of the standard shown.

In view of the overhead gear and the necessity for overhead maintenance, it is advisable to have a circuit carrying lighting units, preferably mounted immediately under the roof and directly over the machines, or, alternatively, plug points for handlamps which should always be properly protected.

With large jacquards the card gear is very bulky and looms fairly wide, and as frequently happens little light from any general system can reach the working plane. It will be necessary in many cases to supplement the general system by units mounted about 3 ft. above the cloth at the front, but in view of the possibility of glare due to low-mounting heights, units having a low-surface brightness are preferable. The general system should, of course, be mounted as high as convenient, say about 10 ft. above and in each gangway, which will ensure some lighting towards the top of the cards. Diffusing units will assist in keepng objectonable shadows to a minimum.

### Perching.

After leaving the loom the cloth is inspected to detect faults. It will be obvious that faults may be very diverse in character, and one can hardly expect that one type of lighting will be equally suitable for the observation of all faults. For example, the weft may be shady, that is successive shuttles may not have been filled with weft of precisely the same colour, or, again, wrongly coloured warp threads may inadvertently have been introduced by the weaver when "piecening up" a broken end. Colour-corrected lighting is necessary. Inspection may also be carried out for thin and thick places in the cloth, in which case the percher may stand behind the cloth, so that the cloth passes between him and the light source; again, surface effects may have to be detected, and a number of these are most easily seen when the light strikes the cloth at a glancing angle.

Grey perching, together with final or finished perching, carried out on the finished goods, are vital processes, and require careful light treatment free from shadow yet of a high level. It has always been customary in the industry to carry out perching by the light from a "north light" window, but the disadvantages have been that perching time is limited by weather and cloud conditions, so that in some cases a "bottle neck" has been caused, since

Fig. 11. Excellent lighting of Tappett and Jacquard looms in the Textile Dept. of Halifax Technical College.

one or two hours per day were all that an expert percher would use.

For a considerable time experiments have been carried out in the provision of artificial daylight windows with varying degrees of success, but in nearly every case with complaints of initial and running costs for the installation, and although production was assisted, an increase in costs of very low magnitude is of paramount importance to an industry where fractions of a penny per pound of finished product is vital.

A parallel beam of light falling normally on to the cloth may be admirable for seeing some faults, but it is most difficult to pick out surface irregularities with such lighting. An intensity for perching of 50 to 100 ft.c. is recommended, and at the present time this is most conveniently obtained by the use of 2-5 ft. fluorescent tubes suitably mounted. If either the type of defect to be looked for or the class of fabric varies considerably it is worth while having the reflector arranged so that the mounting height and angle can both be varied.

### Burling and Mending

After perching the cloth passes forward to the burling and mending department. Burling consists of the removal of foreign matter, such as straw, and pushing knots from the face of the cloth on to the back where they are less likely to lead to surface defects in the finished cloth. Mending consists of inserting missing warp or weft ends where these have broken and have not received immediate attention at the loom. They do not, of course, run the entire length of the piece.

The operative sits at a table or desk and the material is drawn over by hand. Flaws and faults are made good which may necessitate the removal of very fine threads and their replacement by hand. As, of course, coloured threads as well as extremes of light and dark cloth are often involved, considerable eye strain is imposed. At the same time, owing to the very wide range of reflection factors of the cloth which are encountered, it will be necessary either to provide adjustable lighting levels or well diffused high levels, preferably approximating to daylight.

It is quite common for mending tables to be sloping, thus constituting a plane which is nearly vertical, and it would therefore be an added advantage to place units slightly in front of the board itself. Many rooms on this work use high well diffused levels of illuminations, others, where tungsten systems are involved, use colour correction visors, whilst a still greater number still prefer individual lighting for each operator. It is quite noticeable that for work which is absolutely identical in every way individual operators will prefer different lighting levels.

The advent of the fluorescent tubular lamp would seem to offer some solution to this problem, although at the same time creating others by its tendency to stroboscopic effects. This on thin and highly polished needles can be distressing, and careful placing of points will be necessary.

### Finishing

It will be noticed that on the flow chart all the processes in the Finishing Department are shown on a horizontal line. This was purposely done because it is impossible to determine the precise order of the operations. In the main, however, they fall into two classes—wet and dry. Few of the processes require any comment from a lighting engineer's point of view, and general illumination of 6 ft.c. to 10 ft.c. is adequate. In special cases this may have to be supplemented by local lighting: for example, a typical tentering machine has glass panels at the front so that the operator can observe the passage of the cloth through the machine, and local lighting units directed inwards towards the machine are necessary.

In the cropping process it is true to say that the operative can tell from the sound of the machine whether he is taking a reasonable cut and whether the machine is cutting sweetly; nevertheless adequate lighting directed on to the piece at a suitable angle, particularly as it leaves the machine, is desirable. Guards on the cutting cylinders, though very necessary from a safety point of view, do not help either the operative or the lighting engineer, and the importance of good lighting has, therefore, increased rather than diminished since the passing of the 1937 Factory Act.

## The Economics of Textile Lighting

### Supply Problems

In many mills lighting has until recently been the Cinderella of the industry and only looked upon as an unwanted overhead cost. The advent of the I.E.S. Code of values for the textiles will therefore mean a complete revolution in hitherto accepted ratios of lighting to power load. This can be appreciated from a recent statement that the average illumination in the industry was not more than 2 ft.c. The new demands must, therefore, inevitably call for a large increase in lighting units and a complementary demand for fittings conforming to the Lighting Order, 1941.

The textile industry is remarkable for the number of mills each with its own individual power plant, which may vary from the old slow running reciprocating engine, now obsolete from the thermodynamic standpoint, to a very efficient pass-out or back-pressure turbine. The average mill requires large quantities of process steam, and until the stage is reached where central power stations supply low-pressure steam through ring mains to industrial estates, individual mills must retain their own steam raising plant. The additional capital expenditure in providing a pass-out turbine is not heavy, and electricity can then be generated at a cost far below that obtainable from the public supply. Unfortunately the capacity of the alternators in these small individual power plants is limited and little or no provision has been made in the past for a considerable lighting load.

In many of these cases the public supply already

provide a portion of the demand, whilst in others only sufficient is used to meet a minimum annual guarantee for what is actually a stand-by supply. The cost of current in different mills varies tremendously, even when they are of similar size, but in all cases lighting costs must be a very small part in production costs.

### Rationalisation of Tariffs

In large mills on Public Supply the lighting current may be at the power rate and as low as .55d. per unit; in others as much as 3d. or even 4½d. With an increase in lighting demand to Code values, the tendency will be for the former to be increased owing to the rise in ratio of lighting to power load, whilst the latter will probably fall considerably. There is certainly a need for some equalisation of tariffs, a problem which will have to be faced after the war, probably under national control. One firm in particular to which our attention was drawn found itself transferred complete with its machinery and lighting plant from one area of supply to another. Identical lighting demand costs increased by no less than three times, and actually resulted in lighting levels being lowered. Notwithstanding these variations better lighting has made improvements in better health, timekeeping, freedom from accidents due to fatigue, in addition to improved production figures. The average ratio of lighting to power in installed load is about one to nine at present (with poor lighting), whilst in units consumed per annum an assessment of one to eleven is given.

### Installation Costs

It is certain that whilst in the larger mills where maintenance is carried out transmission equipment may be adequate the majority will be faced with the necessity of completely new circuits. In many cases the wiring is old and dangerous, whilst fittings and lamps have never been properly installed. In short, no attempt has ever been made to plan lighting, but it has just been put where the operative asked for it. Other mills are already overloaded on their mains, and at the moment rewiring cannot be considered.

In this latter case the use of high-pressure mercury or fluorescent lighting will no doubt ease the situation considerably on account of the lower consumption per light source, but there are still many mills with a D.C. supply where tungsten lamps only may be installed.

It is evident, therefore, that it is not possible to lay down any formula for estimating the cost of such overhaul and extensions as are entailed which would be acceptable as a basis of calculation.

### Light Sources.

In deciding on his scheme the millowner is invariably faced with the economics of his lighting system, and ignoring all other qualities Table I has been produced on the basis of ten years' working.

Light sources as nearly comparable as is possible

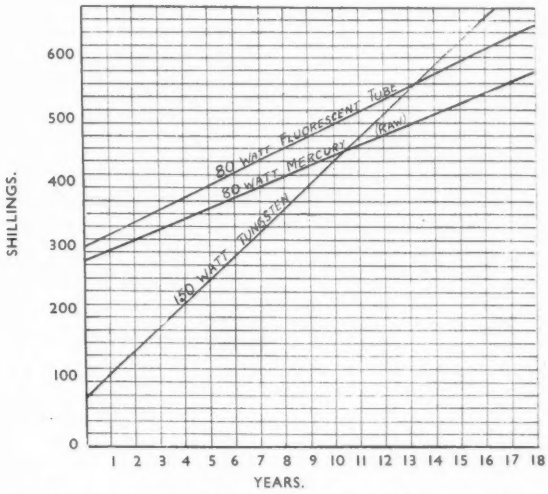


Fig. 12. Installation and running cost of light sources having approximately the same light output.
Current consumption corrected to give same lumens. *April, 1942.*

**TABLE I.—Approximate Installation and Running Cost of Light Sources Having Approx. the Same Lumen Output.**
*April, 1942.*

| Light Source. (1) | Average Lumen output during life. (2) | Life of Lamp. (3) | Cost of Lamp. (4) | Cost of Lamps. (10 years) (5) | Cost of Fittings, Chokes, etc. (6) | Cost of Lamps and Fittings. (7) | Corrected Wattage to give similar Light Output. (8) | Current consumed in 10 years. (9) | Current Cost at 3d. per Unit. (10) | Total Cost. (11) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lumens. | Burning hours. | Shillings. | Shillings. $\frac{(4)\times 10\times 1{,}000}{(3)}$ | Shillings. | Shillings. (5)+(6) | Watts. $\frac{(1)\times 1{,}985}{(2)}$ | kWh $\frac{(8)\times 10\times 1{,}000}{1{,}000}$ | Shillings. $\frac{(9)\times 3}{12}$ | Shillings. (7)+(10) |
| Tungsten 150 watt ... | 1,985 | 1,000 | 4.41 | 44.1 | 20.3 | 64.4 | 150 | 1,500 | 375.0 | 439.4 |
| Mercury (Raw) 80 watt ... | 2,400 | 1,500 | 26.5 | 176.6 | 108.25 | 284.85 | 66.16 | 661.6 | 165.4 | 450.25 |
| Fluorescent Tube 80 watt ... | 2,080 | 2,000 | 36.5 | 182.5 | 126.0 | 308.5 | 76.35 | 763.5 | 190.9 | 499.4 |

*Prices are all inclusive of Purchase Tax (list price). Calculations are over a 10-year period. Burning hours per ann. 1,000.*

have been selected from which it will be seen that on a purely financial basis no benefits can be claimed by the discharge systems over the corresponding tungsten lamps. This is undoubtedly due to the high initial costs of the control equipment and lamps. Many mills generate their own electricity at a very low cost per unit, and therefore any saving in running costs due to the reduced consumption would take so many years to make itself apparent as to be commercially negligible. Apart, however, from costs, it should be borne in mind that possible restrictions react in favour of the use of low wattage, high efficiency light sources.

### Fluorescent Lamps.

The advent of this latest addition to light sources has undoubtedly met the desire of the industry for an approximation to daylight characteristics, which, if commercially practicable, would be desirable at every stage of manufacture. Whilst, as already indicated on a purely purchase and running cost no saving can be shown, the following characteristics will, no doubt, greatly appeal to textile manufacturers:—

(a) *Colour.* The natural white light produced is of better quality than that in other lamps of comparable efficiency, and would go a long way towards satisfying trade requirements.

(b) *Diffusion.* Owing to the tube length and diffusion over its area the light practically eliminates shadows which in certain processes may be extremely objectionable.

(c) *Absence of glare.* Its low surface brightness of 3 candles per sq. in. provides glare-free lighting which would remove many objections to present systems.

(d) *Low temperature.* It produces cool light, this obviating present complaints of overhead heating conditions prevalent with sources operating at higher temperatures, particularly where low-mounting heights are used.

(e) *Immediate starting.* The lamp lights up at full brightness almost immediately switching takes place, thus eliminating the time lag between switching on and full brightness experienced in earlier discharge systems.

(f) *High efficiency.* The tube has a high initial efficiency which although falling fairly rapidly during the first 100 hours or so, gives an average lumen efficiency throughout life of 26 lumens per watt, or, approximately, twice that of the corresponding tungsten lamp. Where current consumption is of paramount importance this will become the major issue.

### Lighting Systems.

Owing to the very wide variation of processes and grouping it would be quite impossible to give a general statement of the most suitable arrangements of systems, the conditions in many mills varying considerably. An endeavour has been made earlier in this paper, however, to indicate in general terms suitable arrangements for the various processes.

## Test Results Obtained on Weaving.

It has been difficult in the past to reach any definite conclusions of the returns to be expected from the textile industry owing to the extremely complicated methods of production as well as the suspicion of operatives associated with the introduction of any new method of illumination. *Data does now exist, however, which gives a clear indication of what results can be expected, and, in addition, certain managements have confirmed identical results from practical tests. One extract from Report No. 81 is worthy of note, as follows:—

> "That in general it appears that an average illumination of about 30 ft.c. on the cloth is necessary for high efficiency in weaving fairly dark cloth."

It was possible in this case to compare an existing installation which was not bad so far as trade standards went, with an improved installation giving approximately the recommended value of 30 ft.c.

It will be appreciated that improvements can be effected in the following ways, either by increased production, improved quality, or both.

### Increased Production.

Increase in production can be effected in one of three ways:—

1. Increase in output due to increased machine efficiency (less time lost through various reasons).
2. Reduction in number of thread breakages.
3. Reduction in number of undetected errors.

The value of the original output was known and an average of the number of thread breakages and time taken in shuttle-changing recorded. If therefore, the original time lost was known and the losses occasioned under the new system obtained, it can be easily ascertained what the net gain really is. This was found to result in a definite increase in output of 5.3 per cent., being the average for the group of looms employed. The main improvement was due to the more rapid detection of warp thread breaks and speedier piecening. Thus, the great importance of seeing, not just seeing, but speed of seeing, played an important part in this increase. No other variable was allowed to intrude, and any gain must, therefore, be directly attributable to the lighting.

Fig. 13 interprets the economic value of this increase, great care having been taken to eliminate false results, costs all being strictly checked at the time of preparation.

It will be seen that the curve falls away after 300 watts per loom of tungsten lighting, and it is safe to say that this is occasioned by the disability of excessive surface brightness which actually interfered with vision. The cloth was dark and of high quality

*"The Effect of Conditions of Artificial Lighting on the Performance of Worsted Weavers." Medical Research Council Report No. 81.

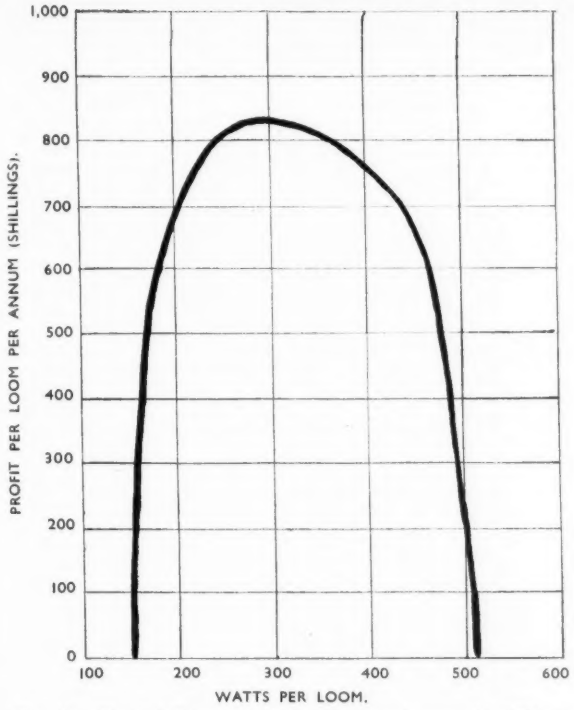


Fig. 13. Worsted Weaving. Value of increased output in shillings per annum.

worsted with a certain amount of lustre. The actual gross profit from increased production is shown as £41 15s. 0d.

### The Effect on Quality

Whilst the output was improved by the better lighting a marked improvement in quality was also shown. This means a reduction in oversight on the weaver's part due to faulty seeing. Thus, where faults occur, either through warp or weft breaks or faulty shuttle changing, cutting out of material with consequent loss may occur. It is possible by improving seeing conditions to detect faults much more quickly as well as to remedy the cause, to change spools more readily, etc., as in the case of hand-operated looms. A summary of the results showed a saving in mending time, comparing the new system with the old, of more than 20 per cent. due to the reduction of faults. Interpreting this result also in monetary terms gives equally interesting results, as shown in Fig. 14.

One point worthy of note is that, unlike the output curve; the quality curve continues to rise steeply as the level of illumination increases. There are less faults leaving the looms, menders' time is saved, and even at 500 watts per loom the curve has not reached saturation point. At 300 watts per loom the gross profit for improved quality is £8 5s. per annum. These results can be translated in terms of £ s. d., as has been done on the accompanying graph showing the summarised results. It follows that to obtain our

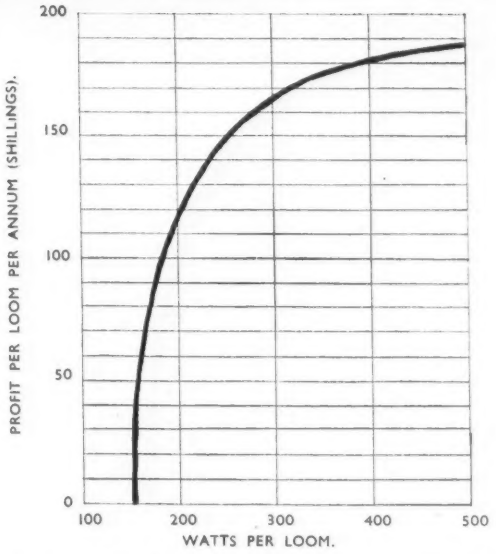


Fig. 14. Worsted Weaving. Profits per loom per annum from improved quality from decreasing faults.

net profits we take our improved quantity and superimpose on it the quality curve and from it subtract our increased costs to secure that output. These increased costs have been very carefully analysed and take account of the entirely new installation with depreciation and interest at 15 per cent. per annum. An interesting point to note is that after 300 watts per loom or 30 ft.c. on the cloth a fall-off occurs, due in this case, no doubt, to the surface brightness of the material. Had other material been

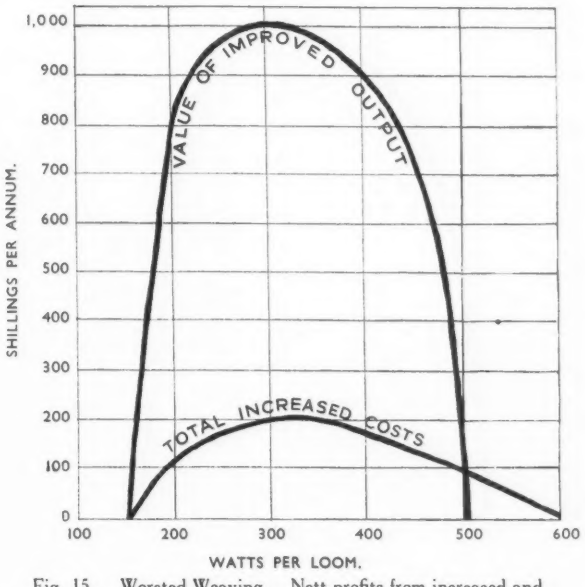


Fig. 15. Worsted Weaving. Nett profits from increased and improved output by better lighting.

employed this could, no doubt, have been exceeded with benefit. Taking the values from the accompany ing graph in monetary terms we shall see the following:—

At 300 watts per loom.

| | |
|---|---|
| The value of the improved output... | £50 p.a. |
| The value of the total increased cost | £10 „ |
| Net profit per loom per annum ..... | £40 |

In other words, better lighting paid for itself five times over.

## CONCLUSIONS

From the foregoing statements of fact the evidence is clear that improved lighting paid. Under certain circumstances much higher lamp wattages have been employed with a consequent improvement in distribution, since higher mounting heights were used. One Yorkshire mill, where carefully compiled statistics for production and mending have been kept, show that the overall efficiency of the looms is in excess of 90 per cent., including stoppage, maintenance, loom repairs, warp changing, and idle time. These looms, incidentally, were automatics.

### Maintenance

Maintenance should allow for cleaning of lamps and fittings at very frequent intervals. In far too many cases this matter is left in the hands of persons with other duties who have to "work in" the cleaning with other duties, as they find it possible or convenient. Such procedure is to be deprecated and shows lack of appreciation of the simple rule "more dirt, less light." Particularly at the present time wastage of light should not be tolerated, and regular cleaning and organised maintenance is as important as the regular cleaning of the factory itself.

It would be difficult to lay down a hard and fast rule for the periods of cleaning since conditions vary widely in the industry. It is, however, safe to say that, generally, regular cleaning should be undertaken at intervals not exceeding four weeks. This period will vary according to the amount of "fly" present. In carding plants it will be necessary to clean down every twenty-four hours, whilst washing and drying plants should not exceed seven days. Cleaning should be arranged as a definite job wherever the size of the installation warrants it and proper adherence to the schedule of cleaning enforced. Maintenance charts, a typical example of which is given, will assist in keeping accurate records.

It is a good practice to arrange for the reflectors to be detachable so that a dirty batch can be taken down at specific times so arranged as not to interfere with production. The fittings should be thoroughly washed with a non-abrasive, not just wiped over. Dirty lamps and fittings can and will, unless corrected, cause an infringement of the Factory Act by reducing an initially good lighting job to such a low lighting level as to fail to meet the stipulation of "suitable and adequate" lighting.

MAINTENANCE & CLEANING CHART
FOR LIGHTING INSTALLATION.

| LOCATION | INITIAL INTENSITY | JAN | | FEB | | MAR | | APR | | MAY | | JUNE | | JULY | | AUG | | SEPT | | OCT | | NOV | | DEC | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL | INT | CL |
| WASHING & DRYING | 8 | 8 | - | 6 | X | 7 | - | (6) | X | | | | | | | | | | | | | | | | |
| CARDING | 8 | 8 | - | 6.5 | X | 7 | - | 6 | - | | | | | | | | | | | | | | | | |
| COMBING | 8 | 8 | - | 6 | X | 7.5 | X | 7.5 | - | | | | | | | | | | | | | | | | |
| SPINNING ROOM No.1 | 12 | 12 | - | 10 | - | 9 | - | (8) | X | | | | | | | | | | | | | | | | |
| DITTO No.2 | 12 | 12 | - | 9.5 | - | (8) | X | 11 | - | | | | | | | | | | | | | | | | |
| DITTO No.3 | 12 | 12 | - | 11 | - | 9 | X | 11 | - | | | | | | | | | | | | | | | | |
| DOUBLING | 12 | 12 | - | (8) | X | 12 | - | 11 | - | | | | | | | | | | | | | | | | |
| WINDING | 12 | 12 | - | 10 | X | 11.5 | - | 11 | - | | | | | | | | | | | | | | | | |

N.B.—Tests to be taken on 1st of each month.

Fig. 16. Mark with X when cleaned. O indicates that owing to big drop in efficiency lamps are nearing end of life and block replacement has taken place.

### Lamp Replacements

It is surprising how few managements in the textiles have given any serious thought to systematic lamp replacements, relying mostly on the principle that the time to replace a lamp is when it ceases to light and not before. This may be a complete fallacy since all lamp manufacturers of repute make lamps so that failures occur within very close burning hour limits. The reasons for this are the physical properties of the materials used and in much the same way that one can use elastic beyond its life, with probable serious results, so many lamps may still light after their economic life though obviously suffering from senile decay. In the case of tungsten lamps, their life is stipulated by B.S.S. 161—1940 at 1,000 burning hours and can only be exceeded by under running with consequent light output reduction in the general case. Mercury discharge lamps have a stipulated life of 1,500 burning hours and the fluorescent lamp 2,000 hours.

In the textiles one is constantly running up against the man who "works the lighting in with other jobs." His only conception of lighting is: (1) if the lamp is burning, and (2) if no complaints are received from the workpeople. If it were possible to assess the time spent by this man in replacing individual light sources as they expire the results would be surprising.

As a possible solution it is suggested that block replacement should be introduced. Thus if all the lamps in any shed are put into circuit at the same time it will be found, provided good quality lamps are used, that their life will be almost identical. Economics indicate that it is a far sounder proposition to replace the whole shed at one period, even though certain lamps may still light, rather than waiting for and replacing individual failures.

Owing to the general conditions in the textiles vibration, voltage variation, particularly where private plant is used, etc., this life is between 800 and 900 burning hours, and replacements at this stage will prove more economical than the general practice of under-running lamps which must result in decreased light output.

In conclusion, the authors desire to express their thanks to the many who have made possible the preparation of this paper.

## DISCUSSION

The CHAIRMAN (Mr. W. HETHERINGTON), in declaring the meeting open for discussion, remarked that the good attendance at the meeting indicated the great interest being taken in the subject of the paper. He also said that much of the data provided by the authors had been awaited for years.

Mr. A. H. OWEN hastened to congratulate the authors of the paper, which was of a highly technical nature, and, as had already been pointed out, would have been most useful some years earlier. Mr. Owen said that in considering light sources it seemed hardly fair to compare the new and in many ways experimental fluorescent lamp with the old and technically perfect tungsten lamp. The fluorescent lamp to-day seemed to be in a relative position to that of the gas-filled lamp during the last war. In 1919 the 100-watt gas-filled lamp was selling at 10s. 6d., and it was nothing like as reliable or efficient as we know it to-day. Improvements in fluorescent lamps were being made almost every day, and prices were high because comparatively few were being made. While we were tied up in the war effort America had been able to organise this new business. Over 22 million units were sold last year at a cost of about 16s. 6d. in equivalent English money for the 40-watt 48-in. tube with control gear, including power factor corrector. We could, therefore, expect that quality would be improved and prices reduced when we could get down to normal. Mr. Owen, however, thought the fluorescent lamp had its limitations. Little had been said about stroboscopic effect. Correct reflectors must be used, otherwise fluorescent tube lighting was not always shadowless. He himself was strongly in favour of the two or even three-unit reflector, and if lamps in a reflector could be staggered in different phases then stroboscopic effect would be avoided. Another advantage of the multiple-unit reflector was that fading was not so noticeable, for it was rarely necessary to replace both lamps in a reflector at the same time.

Dr. N. H. CHAMBERLAIN said that he considered the figure of 3d. per unit as an average cost for lighting current to be unduly high; 1d. per unit would be more nearly representative of average practice. If the total cost figures given by the authors in Table I. were recalculated on this basis, the result was by no means as flattering to the fluorescent and mercury-vapour types of lighting, the actual total cost over ten years being then 189.4 for tungsten, 340 for mercury-vapour, and 372.1 for fluorescent tube lighting. He also pointed out that the same factor would affect the curves given in Fig. 12, in the sense that at 1d. per unit the time required for the tungsten line to cross the mercury-vapour and fluorescent lines would be nearer twenty years than ten.

He also drew attention to Fig. 15, in which the bottom curve showed ostensibly the total increased cost per loom, in shillings per annum, for various intensities of illumination. According to this curve, the total increased cost at 600 watts per loom was the same as at 150 watts per loom, namely, zero. It was difficult to see how an increase of 450 watts per loom could have been achieved at no extra cost.

Mr. N. HODSON said that he would like to thank the authors because, as he had been taking part in the investigation of similar problems in the cotton textile industry, he could appreciate the amount of work involved in the preparation of this paper. There was one point, however, that he wished the authors had not included in the paper, i.e., the reference to the high cost of diffused lighting in the weaving shed. He was quite ready to agree that there was a great deal of truth in the statement, but, if such was the case, how was it possible to substantiate the usefulness of fluorescent tubes. Apart from this point, he felt that there was very little with which to quarrel in the paper, which would be of great assistance to the Manchester Centre (North-Western Area).

Mr. W. F. POGSON said that he would like to congratulate the authors not only on collecting the information and presenting it in the form of a paper so clearly, but for having the courage to go into the economics of this matter and putting some information on record which, of course, could be subjected to criticism.

He would be glad if the authors could explain why they recommended an area of lighting of high value of 1 ft. in diameter in the healding process, because surely in a minimum field of vision such as that, the marked contrast between the very small area at 100 ft.c. and the rest of the lighted area at say 10 ft.c. would make it difficult for the operators of the machine, and he felt that he could not accept this as being correct.

Mr. Pogson said that he could not reconcile the criticism as to the elaboration of an installation with industrial diffusers and the justification of the fluorescent tubular lighting, which in similar circumstances would cost twelve times as much to instal and would only give the same number of foot-candles. He also wondered whether it was correct to take 1,000 hours as a basis of yearly burning in a textile mill. He felt that it would have been more correct to have taken between 600 and 650 normally and 3,000 to 4,000 hours if the factory was working a night shift. In any case, increased usage should normally bring about reduction in the price of electricity.

In the paper it stated that when the illumination was increased above 30 ft.c. in worsted weaving, a reduction in increased output was apparent. This, he said, did not seem right. He put forward the explanation that either there was insufficient diffusion or that the direction of the light on the cloth and its constituents was wrong. A recommendation of 25 to 50 ft.c. for weaving went right against the I.E.S. Code. It was not explained how lighting in excess of 320 watts per loom cost less than did that figure. If reduction in the number of points was involved, then it was likely that the direction and diffusion would suffer. As regards the price of electricity, Mr. Pogson ventured the hope that in the future something nearer the 1d. per unit mark might be applicable to the textile mills. He stated that in most cases, however, they did not buy at 3d. per unit because they preferred to use their own steam to make it.

Mr. M. C. TONER said that he did not wish to "gild the lily," but he felt that it was the finest paper that Leeds had ever had on the subject. He felt that it would have been better had the investigation been carried through to finality and included the process of manufacture right through to the finished garment, so including the tailoring trade. Mr. Toner asked if, in the opinion of the authors, sight boards would not have been of assistance in reflecting diffused light through the healds. He mentioned that the new I.E.S. Code had omitted a reference to artificial daylight in the case of burling and mending. He went on to say that there were very few cases in the mills where sufficient daylight was available all the working time in winter. Most unsatisfactory results were obtained when the daylight was mixed with the tungsten lighting. The tungsten lighting should be "corrected" for this work.

Mr. Toner said that the problem of voltage drop was a serious one in the textile mills, which the lighting engineer would have to combat in great numbers. When the mill was shut and readings taken the standards were good, but if the readings were taken when the mill was working the standards had dropped considerably and might be considered bad. He said that experiments he had carried out many years ago in the West Riding mills involved the use of extensive type reflectors, and the most satisfactory lay-out was based on the use of two 100-watt units in the gate and one 100-watt in the middle of the back of the loom. Mr. Toner said he was surprised at the categorical denial by the authors that any colour matching was done in the dyehouse, but that it was all done in the colour matcher's office. He said that colour discrimination was demanded by the largest group of cloth finishers in the country in the dyehouses.

Mr. J. H. MOLLAN said that he would like to query the statement that maintenance could be greatly simplified by mounting clear glass visors on the face of the fittings. The manufacture of an absolutely airtight fitting was costly and difficult, and the cooling of the units when switched off inevitably led to the "fly" or fine fibres being drawn into the unit, where it settled on the inside face of the glass visor. As this visor had to be removed for cleaning owing to the absorption of the light by the "fly" which settled on it, it did not necessarily follow that maintenance was simpler; in

the case of the open dispersive reflector the " fly " could be cleaned off very much more readily and, in any case, the depreciation was less rapid with the open type dispersive reflector, as the " fly " which would settle on the cover glass fell away from the unit. In the case of carding machines the authors stated that it was sometimes impracticable to illuminate the top horizontal surface, particularly as most rooms were low and headroom limited. The main reason, however, why units were never mounted over cards themselves (and this despite Mr. Jackson's assurance that lamps never break and fall) was that in the case of a lamp or unit falling from its housing and becoming entangled with the card clothing or the material passing through the carding engines, damage would be considerable and repairs costly. Concerning perching, the ideal arrangement of fluorescent tubes, as ascertained by practical tests, appeared to be—one horizontal unit over the window and two vertical units at each side of the window normally used for the admission of daylight for this process.

Mr. R. Pye (*communicated*): Mr. Jackson made the rather sweeping statement that the fluorescent lamp was no use whatever as a colour matching medium. I disagree with that statement entirely. For the last three years I have had access to some of the laboratories of the leading manufacturers in this country. I have devised, created, and in some cases erected, the equipment for some colour matching rooms. I am not a colourist and I have no experience in the dyeing industry other than being called in to devise these so-called colour matching rooms. I do know they have met with some considerable success, have been in use regularly until the present day, and I know that in some cases they are far more satisfactory than the old Lamplough fitting. I can substantiate these claims quite definitely, and I am prepared to do so should the necessity arise.

Mr. Imrie-Smith (*communicated*): The authors are to be congratulated on their general survey of what, from a lighting point of view, is a very complicated industry. Anyone experienced in such work will fully endorse their statement that " owing to the very wide variation of processes and grouping it is impossible to give a general statement of the most suitable arrangement of fittings." The statement, made under the Weaving heading, that " good general lighting is usually preferred, but, due to the presence of overhead obstruction of one sort and another, localised general lighting is often necessary " also deserves emphasis as expressing a dominant note in the treatment of practically all process departments. Unfortunately, the " preferred general lighting," like the typical installation of small wattage local fittings, still presents the facile solution to the unwary.

The expressed desire for uniformity of illumination between mule spinning frames, however, rather masks one of the main points in this process. A general lighting installation would give the desired uniformity, but in operation the piecer, perceiving a break, follows up the carriage and has to seize the broken end and do the rejoining at the moment the mule is close to the stationary part of the frame. This actual joining is practically instinctive, but it does mean that the fittings have to be placed so that the dropped end is not enshadowed at the moment when the piecer is stooping or reaching over the mule. This consideration leads to the fittings having to be placed relatively close to the front of the stationary part of the frame, even if some sacrifice has to be made in the central area. The fluorescent tube installation illustrated appears to conform with this requirement, although it looks as if in this case dimensions have been favourable from both aspects.

The mention of the back lighting of looms is particularly important. The value of this in assisting vision when tracing broken ends through the healds, apart from any question of setting up the loom, is not generally sufficiently appreciated, and back lighting is often one of the points most debated in an installation.

With regard to looms, it is rather difficult to understand the authors' misgivings of the industrial diffuser installation illustrated. As they rightly point out, the number and position of the fittings for this operation are controlled by the type of arrangement of looms. They follow their observations by remarks on " going part " shadows, etc., all of which support the justification of diffusing type fittings, so it is hard to see on what basis their criticism is founded.

Whilst approving much of the paper, one must join issue on the economic section, a subject containing very many pitfalls. Recently I had occasion to resurvey the computation of light cost comparisons, and definitely concluded that such generalisations are totally unreliable; even when dealing with a specific case a diversity of answers can be produced except under very specific conditions that can be regarded as only applying to the particular installation under consideration.

Space only permits one point in regard to the handling of data as given in Table 1. The adjustment for comparison purposes given in Column 8 is unsound and is really the old general lighting bogy in another form. With correctly planned lighting the number of light sources of comparable size must remain constant, irrespective of their being tungsten or discharge lamps. The result is that in *practice* one would be obliged to replace each 150-watt lamp with an 80-watt fluorescent tube so that, allowing 10 watts choke loss, the ratios in column 8 should read 150, 90, 90. This point is frequently overlooked, although the authors themselves support this fact in their description of loom lighting with 80-watt tubular lamp fittings in which they indicate how the looms have to be studied.

Turning to the graphs, one is struck by the abnormally sharp drop of graph No. 13. This is so unusual that one cannot help forming the opinion that there must have been some misapplication in the installation which increased with increase of wattage. An example of such a case would be the use of tungsten lamps in open-type reflectors, this leading to marked increases in the direct as well as the indirect glare as the wattage is increased, even if standard reflectors, appropriate to the wattage, were employed. The authors might like to apply a correction to graph No. 15 where one is led to the startling conclusion that it is cheaper to provide 500 watts per loom than 300 watts.

The Authors, in reply, expressed agreement with Mr. Owen's remark that purchase prices are regulated by the supply of and demand for any commodity. There was, however, a distinct difference between the magnitude of the U.S. market and that of the United Kingdom. Consequently, in their opinion, one never could expect manufacturing costs to be as low in this country. In any case, changes in cost had been anticipated by dating the charts to current prices in April, 1942.

The authors were well aware that whilst stroboscopic effects are present to a limited degree with the fluorescent lamp, they are much less than those occurring with raw mercury or other A.C. operated devices, due to the persistence of the fluorescent powders. Experience proved that, for general purposes, there were no distressing stroboscopic effects produced by the tubes, but in any case they could be minimised by adopting the same procedure as for other discharge systems.

The figure of 3d. per unit was arrived at after very careful investigation, and gave a fair average price obtaining for lighting supplied from public mains. What Dr. Chamberlain had apparently overlooked was the existence of possible basic charges in addition to a low unit charge. In fact, evidence existed of a charge of 4½d. per unit for industrial lighting in certain areas. It was not universal for the whole of the textile processes to be carried out by a single firm. For example, weaving sheds were sometimes operated by small firms, and it was not unusual for small firms to spring up for the carrying out of one or two processes. In such cases the cost of current might be rather high for two reasons: first, that the installed load would be relatively small, and, secondly, that the building would probably be more modern and would have better daylight facilities.

In regard to Fig. 15, it should be noted that all costs were given as *increased* costs over the original system and not total costs. Increased costs included weavers' wages, and as production decreased with higher lighting values than 300 watts per loom, consequently piece-work pay declined heavily. The falling curve thus indicates a reduction in workers' pay amongst other costs.

Table I. showed the cost of lamps, fittings, etc., over ten years (given in column 7). Possibly owing to the small print on the copies of paper the questioner had failed to see the explanatory identification figures. If to this column

the current cost over that same period at 3d. per unit was added, the result was obviously the total cost of the installation, less wiring, etc.

Mr. Hodson queried the value of fluorescent tubes over other diffusing sources. The paper had distinctly indicated other properties possessed by the tubes which offset the additional costs. It would be misleading to compare fluorescent lighting on a pure cost basis.

Replying to Mr. Pogson, the suggested area of 1 ft. in diameter was really greater than that on which the operator registered severe visual perception. The area had been decided after several tests, which proved the unsuitability of general lighting alone. It should be noted, first, that general illumination existed in addition to the local lighting and therefore extreme contrasts were avoided. Secondly, statistics showed that the 1,000 hours taken per year was fairly representative. In any case, it was fairly easy to substitute other figures if desired. Thirdly, M. Pogson had apparently overlooked the statement that the reason suggested for the fall-off in production when levels exceeding 30 ft.c. were reached was the cloth surface brightness. It had been indicated in the paper that on other types of cloth with different texture, higher values could no doubt be used with advantage. Thus, there was no deviation from I.E.S. Code values. Fourthly, the point as to whether directional lighting was preferable to diffused lighting was debatable. It was certain that some defects not visible under diffused lighting became visible under directional lighting. The tests taken, however, did not confirm material benefit, although they were severely restricted by having to use standard equipment. The position is open to further experiment.

In reply to Mr. Toner, it was stated that sight boards had been tried in various ways, but the main difficulty was one of maintenance, which proved to be costly. Regarding colour matching, the authors reiterate that, in the vast majority of dyehouses this takes place in the colour matcher's office.

Mr. Mollan's note regarding the simplification of maintenance by the use of clear glass visors on fittings, might well apply where fine dust such as that in foundries was present, but experience in large plants in the woollen and worsted industry did not agree with his remarks. Evidence collected by the authors showed that a considerable saving in maintenance time did occur in carding rooms where these visors were fitted, and the accumulation of "fly" on the inside of the visor was negligible.

With reference to the mounting of fittings over carding plants, this had never been suggested, as the authors were well aware of the difficulties, but top illumination had been secured by directional lighting, which now, however, would conflict with the requirements of the Lighting Order, 1941.

With regard to Mr. Pye's communication, in some cases fluorescent tubes in ordinary commercial reflectors had been installed as colour-matching units for north daylight conditions. This had not been satisfactory because the spectrum of the light from the fluorescent tubes differed appreciably from north daylight. The authors never intended to deny that specially chosen tubes mounted in special reflectors could be used as colour-matching units. They did, however, wish to emphasise that the uncorrected light from the tubes was not equivalent to north daylight.

Mr. Imrie-Smith's attention may be directed to Fig. 9, where the "going part" shadow is clearly seen. This illustration is a "close up" of the diffused system shown in Fig. 8. One solution, which completely minimised this shadow, has been the use of a fluorescent tube in a suitable fitting mounted above and across the "going part" and at right angles thereto. Various installations from which graph 13 was calculated utilised tungsten lamps in open-type reflectors.

In regard to Fig. 15 we may remind Mr. Imrie-Smith that the "value of improved output" curve is assessed on increased output and improved quality, and that both curves present values *over* those of the original lighting system. The lower curve is obtained by the summation of the costs of current and lamps and depreciation, but the greater part is that of weavers' wages, which rise or fall according to output. At 500 watts per loom, the weavers being on piecework, the output decreased in value six times. Hence the steep fall off in the increased costs.

# PROVISIONAL PROGRAMME OF MEETINGS (SESSION 1942-1943)

In what follows a provisional list of meetings in prospect is given. All available particulars of forthcoming events have been included, but in some instances programmes have not yet been completed. Local conditions may lead to certain changes, for example, in the time of meeting, but any such modifications will be announced to members interested. In the meantime members are advised to keep the following list for reference purposes.

## SESSIONAL MEETINGS IN LONDON

*Unless otherwise announced Meetings will be held at* **5.0 p.m.**

**1942.**

**Tuesday, Oct. 13th.** Address by the President (MR. R. O. ACKERLEY). *To be held at the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2.*

**Tuesday, Nov. 10th.** A Paper on **The Lighting of Docks,** by MR. THOS. NISBET.

**Tuesday, Dec. 8.** A Discussion on **Guidance, Specification and Legislation of After-War Lighting,** to be opened by MR. A. G. HIGGINS.

**1943.**

**Tuesday, Jan. 12th.**
**Tuesday, Feb. 9th.**
**Tuesday, March 9th.**
**Tuesday, April 13th.**

Papers on **Revised I.E.S. Code; Predetermination of Measurements of Industrial Lighting; Lighting of Public Buildings; Visual Efficiency and Luminosity Curves at Low Illuminations; Maintenance and Use of Photometers of the Photo-Electric Type, etc.**

**Tuesday, May 11. Annual General Meeting.** Address by SIR JOHN HERBERT PARSONS.

## LEEDS (NORTH MIDLAND) CENTRE

(*Hon. Secretary:* DR. E. C. WALTON, College of Technology, Cookridge Street, Leeds 2.)

*Unless otherwise announced, meetings will be held at the College of Technology, Cookridge Street, Leeds 2, at* **5.0 p.m.**

**1942.**

**Oct. 20th. Informal Luncheon** at the Metropole Hotel, King Street, Leeds. 12.30 for **1.0 p.m.** Followed by a Sessional Meeting and **Address by the President** (MR. R. O. ACKERLEY) at **2.30 p.m.**

**Nov. 9th.** Details to be announced later.

**1943.**

**March 8th.** A Paper on **The Calculation of Illumination from Large Area Sources,** by MR. P. HARTILL.

**April 5th.** A Paper on **Applications of Fluorescent Lighting,** by MR. W. R. STEVENS.

**May 3rd. Annual General Meeting** followed by a Sessional Meeting. **Address by the Chairman** (DR. J. W. WHITAKER).

## PROVISIONAL PROGRAMME OF MEETINGS (SESSION 1942—43)

### MANCHESTER (NORTH WESTERN) CENTRE

*(Hon. Secretary:* ALAN H. OWEN, 11, Albert Square, Manchester, 2.
*Unless otherwise announced, Meetings will be held in the Reynolds Hall, College of Technology, Sackville Street, Manchester, at* **2.30 p.m.**

**1942.**

**Oct. 22nd.** Address by the President (MR. R. O. ACKERLEY).

**Nov. 19th.** A Paper on **Street Lighting—Past, Present and Future,** by MR. G. H. WILSON.

**Dec. 17th.** A Paper on **The Efficiency and Surface Brightness of Diffusing Lighting Fittings,** by DR. S. ENGLISH.

### BIRMINGHAM (MIDLAND) CENTRE

*(Hon. Secretary:* C. J. ALLDERIDGE, 10, Boscobel Road, Walsall.)
*Unless otherwise announced, Meetings will be held at the Imperial Hotel, Temple Street, Birmingham, at* **6.0 p.m.**

**1942.**

**Sept. 25th. Chairman's Address** (MR. W. J. C. DAVEY) on **"Aids in Lighting Surveys."**

**Oct. 23rd.** Paper by MR. J. H. NELSON.

**Nov. 20th.** Address by the President (MR. R. O. ACKERLEY).

**1943.**

**March 26th.** A Paper on **Diffusing Glassware** by DR. S. ENGLISH.

**April 30th.** A Discussion on **Post War Street Lighting.**

**June 12th. Lighting Problems**—solved by "The Brains Trust."

### GLASGOW (SCOTTISH) CENTRE

*(Hon. Secretary:* M. W. HIME, E.L.M.A. Lighting Service Bureau of Scotland, 29, St. Vincent Place, Glasgow, C.1.)
*Unless otherwise announced, Meetings will be held at "Cadoro" Restaurant, Glasgow, at* **6.0 p.m.**

**1942.**

**Oct. 28th.** Address by the President (MR. R. O. ACKERLEY).

**Dec. 9th. Problems** night.

### NOTTINGHAM (MIDLAND) CENTRE

*(Hon. Secretary:* C. S. CAUNT, 62, Thackerays Lane, Woodthorpe, Nottingham.)
*Unless otherwise announced, Meeting will be held in the Lecture Theatre of the City of Nottingham Gas Dept., Parliament Street, Nottingham, at* **5.30 p.m.**

**1942.**

**Sept. 4th. Annual General Meeting.**

**Oct. 2nd.** A Paper on **The Eye, Its Functions and Reactions,** by MR. H. H. BARBER.

**Nov. 6th. Problems Meeting.**

### NEWCASTLE (NORTH EASTERN) CENTRE

*(Hon. Secretary:* S. D. LAY, Ellison Buildings, Ellison Place, Newcastle-upon-Tyne 1.)
*Unless otherwise announced, Meetings will be held in the Minor Hall, Oxford Street, Newcastle-on-Tyne, at* **5.30 p.m.**

**1942.**

**Oct. 7th.** A Paper on **The Behaviour of the Eye as a Physical Instrument,** by MR. S. M. COX.

**Nov. 4th.** Discussion on **The Lighting of Post-War Buildings.**

**Dec. 2nd.** A Paper on **Living and Lighting in Post-War Buildings,** by MR. C. A. HARDING.

**1943.**

**Jan. 6th.** Conversazione and Tea, to meet the President (MR. R. O. ACKERLEY).

**Feb. 3rd.** A Paper on **The Bases and Structure of an Industrial Lighting Code,** by MR. H. C. WESTON.

**March 3rd. Annual General Meeting** followed by a Paper to be announced later.

### SHEFFIELD (NORTH MIDLAND) GROUP

*(Hon. Secretary:* J. A. WHITAKER, Magnet House, Fitzalan Square, Sheffield, 1.)
*Unless otherwise announced Meeting will be held in the Meeting Room, Central Library, Surrey Street, Sheffield (entrance in Tudor Place), at* **6.0 p.m.**

**1942.**

**Oct. 21st. Informal Luncheon** to be held at the Royal Victoria Hotel, Sheffield, at **12.30 p.m.,** followed by the Annual General Meeting. Address by the President (MR. R. O. ACKERLEY).

**Nov. 4th.** A Paper on **The Manufacture of Glassware,** including Types for Illuminating Purposes, by MR. HUGO WOOD.

**1943.**

**Feb. 3rd.** A Paper on **Problems to be Faced by an Electrical Installation Contractor,** by MR. H. WHEELER.

**Mar. 3rd.** A Paper on **Planning and Design of Lighting Installations,** by MR. W. G. THOMPSON.

**April 7th.** A Paper on **Fluorescent Lighting,** by Mr. R. MAXTED.

**May 5th.** A Paper on **Light Adaptation, with Special Reference to Working Conditions,** by MR. W. J. WELLWOOD FERGUSON.

**Sept. 8th.** An Open Discussion. Speakers: (1) a representative of H.M. Inspectorate of Factories, (2) a Works Engineer, and (3) an Electrical Installation Contractor.

### CARDIFF (SOUTH WALES) GROUP

*Hon. Secretary;* S. G. TURNER, Metropolitan Vickers Electrical Co., Ltd., Mervyn House, Frederick Street, Cardiff.

*Unless otherwise announced Meetings will be held at the Cardiff Corporation, Electricity Department, Demonstration Theatre, Cardiff, at* **3.30 p.m.**

**1942.**

**Oct. 15th. Annual General Meeting** followed by a Paper on **Infra-Red Radiation and Equipment—their Application to Industrial Processes** by MR. R. MAXTED **(3.0 p.m.).**

**Nov. 19th.** A paper on **The Progress of Lighting in Industry** by MR. S. G. TURNER.

**Dec. 10th.** Address by **the President** (MR. R. O. ACKERLEY).

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## Additions to List of Members.

CORPORATE MEMBERS:—

Bird, G. .....58, Glen Gate, South Wigston, LEICS.

Davenport, F. W....37, Forest Hill Road, Sheldon, BIRMINGHAM, 26.

Fowler, W. ....."Bradley," 59, Westfield Road, LEICS.

Hodgkins, W. I. ...33, Rutland Street, LEICESTER.

Kersey, R. W. .....26, Selcroft Road, Purley, SURREY.

Lancaster, J. E. ...11, Somerdale Avenue, Odd Down, BATH.

Paterson, R. H., Jnr. "Moorside," Mildmay Road, NEWCASTLE-ON-TYNE, 2.

Waldron, F. J. .....1, Oakfield, Cottles Oak, FROME.

ASSOCIATES:—

Chamberlain, C. J. 117, Lower Oldfield Park, BATH.

# THE EYE

By J. R. MITCHELL, M.C., M.B., Ch.B., D.P.H.

*(Summary of a Lecture delivered before the Birmingham Centre (Midland Area) of the Illuminating Engineering Society on Friday, April 17th, 1942*

While none would willingly sacrifice any one of his senses, there can be no doubt that the sense of sight or vision is the dominant faculty in life. It is, in fact, the fundamental sense, for whatever impression may reach our consciousness through other senses it is always associated with, or interpreted by, a visual concept of the origin of the impulse.

The faculty of vision is a complex of three factors or portions:—

(1) **Physical.** The eye, an optical instrument designed to focus accurate images of external objects on a sheet of sensitive tissue, the retina.

(2) **Physiological.** The conversion of light stimuli into nervous impulse which is conveyed to the brain, where perception takes place.

(3) **Psychical.** Recognition of the perceived impulse, its comparison with similar forms in past experience and its correlation with other memories, such as hearing, speech, writing, etc.

### Structure of the Eye

Let us consider these in a little more detail.

The eyeball is embedded in a cushion of fatty tissue in a hollow of the skull termed the orbit. It is globular in shape and consists of three coats or layers. These coats from without inwards are:—

(1) **The Fibrous coat;** tough and strong, the front part composed of special fibres so that it is transparent; this transparent portion is termed the *cornea*.

(2) **The vascular or bloodvessel coat,** largely composed of a network of bloodvessels with pigment in the spaces. About the level at which the cornea joins the posterior portion of the fibrous coat, the vascular coat is thickened by the addition of muscle fibres forming a projection called the *ciliary body*, which forms a ring around the inside of the eye. From this ring-like projection the vascular coat is continued to form a curtain across the inside of the eyeball. This curtain is termed the *iris* and has a central aperture, the *pupil*. Since the iris contains muscle fibres the pupil opening is capable of variations in size.

(3) **The nervous coat,** the *retina*, is the innermost coat of the eye. It is composed of specialised nervous elements called *rods*, *cones*, and pigment cells. These nervous elements are found only in the posterior part of the retina, up to the level of the ciliary body. The coat is, however, continued forward as a lining to the vascular coat in the form of a layer of cells more or less pigmented. Nerve fibres in connection with these rods and cones converge to an opening in the back of the eyeball and pass out as the *optic nerve*. By relays of fibres impulses are carried to the surface or cortex of the brain, where perception occurs.

In addition to the coats of the eye, the contents require a moment's consideration. The front part of the globe contains the *aqueous humour*, chiefly salt and water. The posterior part is occupied by a jelly-like substance, the *vitreous humour*. Between the two, immediately behind the iris, is the *crystalline lens*. This is a bi-convex mass of transparent fibres contained in a transparent capsule. The lens is retained in position by fine fibres which attach it to the ciliary body. Action of the muscle fibres in the ciliary body is able to alter the tension of

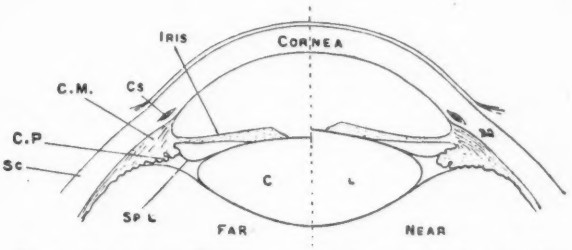


Fig. 1. Diagram to illustrate accommodation. On the left, the form taken by the lens at rest and viewing distant objects is shown; on the right, that when accommodated for near objects.

*Sc.*, sclerotic; *C.P.*, ciliary processes; *Sp.L.*, suspensory ligament; *C.L.*, crystalline lens.

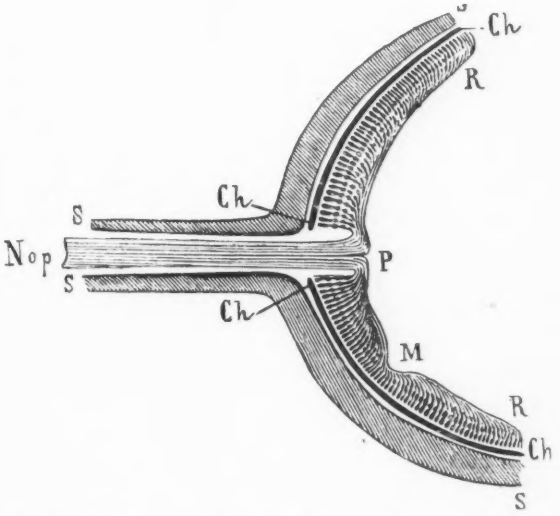


Fig. 2. To show connection of optic nerve with rods and cones.

*Ch*, choroid; *S*, sclerotic; *R*, retina; *Nop*, optic nerve; *P*, point of entrance of optic nerve, blind spot; *M*, yellow spot of retina.

the capsule of the lens so that the curvature of the lens can be increased or diminished according to need.

The orbit is closed in front by the eyelids, composed of skin and of muscle fibres, the action of which is to close or open the aperture between the lids. On the inside the eyelids are lined by a layer of moist mucous membrane, which covers also the globe of the eye up to the margin of the cornea; this is termed the *conjunctiva*, and serves to maintain the necessary moist condition of the cornea.

There are six extrinsic muscles for each eye. These by combined action can move the eyeball in any direction, and muscular actions are so co-ordinated that the two eyes are directed to any desired object at the same time.

**Protection from injury** may be considered under two heads:—

(a) Physical: eyebrow; lids; eyelashes; mobility in the orbit and on fatty tissue, tending to convert direct into tangential force.

(b) Thermal: vascular coat.

Fig. 3. Blood-vessels of the Eye (Schematic). (After Leber.)

The retinal system of vessels is derived from the central artery, *a*, and the central vein, $a_1$, of the optic nerve, which give off the retinal arteries, *b*, and the retinal veins, $b_1$. These end at the ora serrata, *Or*.

The system of ciliary vessels is fed by the short posterior ciliary arteries, $c_1$, $c_1$, the long posterior ciliary arteries, *d*, and the anterior ciliary arteries, *c*. From these arise the vascular network of the chorioidal capillaries, *f*, and of the ciliary body, *g*, and the circulus arteriosus iridis major, *h*. From this last spring the arteries of the iris, *i*, which at the lesser (inner) circumference of the latter form the circulus arteriosus iridis minor $k$. The veins of the iris, *i*, of the ciliary body, and of the chorioid are collected into the vasa vorticosa, *l*, some veins, *m*, however, that come from the ciliary muscle leave the eye as anterior ciliary veins, *c*. With the later Schlemm's canal, *n*, forms anastomoses.

The system of conjunctival vessels consists of the posterior conjunctival vessels, *o*, and *m*. These communicate with those branches of the anterior ciliary vessels which run to meet them; that is, with the anterior conjunctival vessels, *p*, and form with these the marginal loops of the cornea, *q*. *O*, optic nerve; *S*, its sheath; *Sc*, sclera; *A*, chorioid; *N*, retina; *L*, lens; *H*, cornea; *R*, internal rectus; *B*, conjunctive.

### The Eye as an Optical Instrument

With this rough anatomical outline let us consider the eye as an optical instrument. It is often likened to a camera, and the simile is quite apt. In a camera we have a box blackened inside, containing a lens by which images of external objects can be focused upon a sensitive plate or film. The amount of entering light can be regulated by a stop, with varied size of aperture, placed in front of the lens. Similarly, the eye is a spherical box, black inside; the retina functions as the sensitive plate, while the iris with its variable aperture, the pupil, acts as a stop. The pupil is automatically adjusted, contracting when the incidence of light is increased and dilating in low illumination.

In the eye the lens of the camera is replaced by the whole refracting system—the cornea, the aqueous humour, the crystalline lens, and the vitreous humour.

The normal eye is usually focused for distant objects; when near objects are viewed the ciliary muscle comes into action so that the lens is increased in curvature and the refracting power of the eye thus increased. In every eye there is, of course, a limit to this power of *accommodation*, as the increase in refracting strength is called. If a book is gradually brought nearer to the eye a point is ultimately reached at which the print becomes indistinct and no effort of accommodation serves to focus it and make it legible. This point is called the *near point*, and is five or six inches from the normal eye. As we become older, however, our tissues tend to lose their elasticity; it becomes increasingly difficult to alter the curvature of the lens and so to accommodate for near vision. Therefore, we have to hold our paper farther and farther from our eyes or, better still, we procure "reading glasses" which will provide the

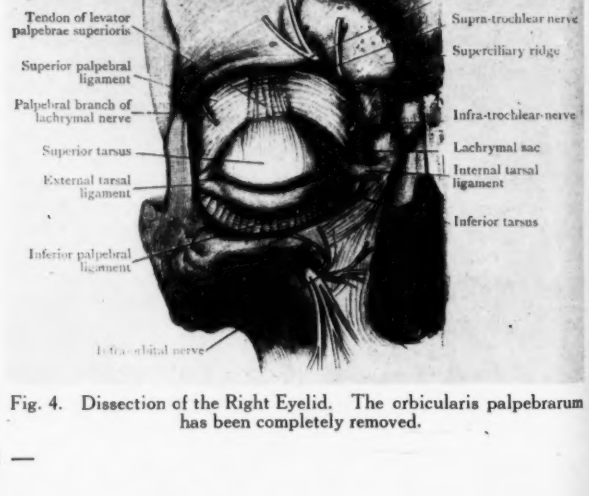


Fig. 4. Dissection of the Right Eyelid. The orbicularis palpebrarum has been completely removed.

extra refracting power denied us by our hardening crystalline lens.

Certain fairly common defects in the optical apparatus may be considered shortly here:—

(1) **"Long sight."** Here the eyeball is shorter than normal so that images of distant objects would be focused behind the retina. Even for distant vision, therefore, some effort of accommodation is necessary and correspondingly greater effort for near vision. The ciliary muscle is thus more or less in action all the time.

(2) **"Short sight."** This is the opposite defect; the eyeball is longer than normal. Images of distant objects are focused in front of the retina and the eye is, as it were, permanently adjusted for near vision. No effort of accommodation can overcome this, so that the individual, to secure clear distant vision, must have a suitable spectacle lens.

(3) **"Astigmatism."** This is due to a greater curvature of the refracting surfaces of the eye in one meridian than in others. The defect is usually in the cornea. As a result two straight lines crossing one another at right angles cannot both be accurately focused at the same time, so that blurring of vision at any distance ensues. This can be compensated little, if at all, by accommodation, since it would entail the ciliary muscle acting more in one meridian than in another.

Let us look now at what happens when light falls upon the retina. We have seen already that the pupil contracts in order to regulate the amount of entering light. In the retina itself several reactions occur. In general, there is alteration in the chemical reaction and in the electrical potential of the retina along with shortening of the cones and bleaching of the "visual purple," a substance contained in the rods.

The peripheral regions of the retina contain chiefly rods with very few cones. This part of the retina is colour-blind, but is sensitive to light of low intensity and of short duration; it therefore readily appreciates movement at night, although perception of detail is poor. At the centre of the retina is a small specialised area, the *yellow spot*. In this area cones greatly predominate and in its centre cones alone are present. This is the point of greatest acuteness of vision and is capable of perception of very fine detail. Colour is perceived, but appreciation of light of low intensity is poor.

These various reactions to the stimulus of light give rise to "nerve impulses," the exact nature of which is unknown. Certain it is that these impulses pass up the optic nerve and are ultimately received in the brain, where they excite action in the nerve cells. What the process is we do not know, but as a result of it perception takes place and the impulses are recognised as visual impressions. The complexity of the process will be appreciated when we remember that, as in the case of the camera, the image on the retina is reversed and upside down, yet it is correctly orientated by the brain. Furthermore, the brain receives two images of any object, one from each eye, and since the eyes are some 60 mm. apart, these two images will be slightly different. Yet the brain is able to fuse these images, thus gaining an impression of depth and position—stereoscopic vision.

So far the external object has been seen and perceived by the brain; before it can be recognised, however, the brain must recall similar impressions in past experience. These are stored in our "visual memory." It is as though the brain kept a card index file of all past impressions and is able to pick from the file a card with the same visual outline as the one at the moment under consideration. The close association of vision with the other faculties and its dominant nature have already been mentioned. Take the apparently simple matter of writing to dictation, as we all do some time or another. Suppose we are asked to make a note of the number Central 7,000. First we must hear the word "central"; then a message goes to our visual memory centre to pick out the form which corresponds to the sound of the word; next a message goes to our writing centre and the hand is instructed to make the necessary movements of writing. How dominant is vision over all the other senses is, I think, demonstrated by the development of these other senses when a person becomes blind. So long as he had sight he was content with a quite poor development of his other faculties, his main dependence being upon his sense of vision.

### The Visual Sense.

Visual sense is made up of three components:—

(1) The light sense, which enables us to perceive light as such and in varying degrees of intensity. The longer the eye is kept in the dark, the more readily do we perceive light of low intensity, the retina being said to have become "dark adapted." Hence the advisability of shutting the eyes for a few moments before going out during black-out and an explanation of why, after we have been out a few moments, our vision improves. Similarly, on entering an area of more intense illumination, after a short period of dazzling, the eyes become "light adapted."

(2) The form sense, which allows us to recognise the form of objects in the external world. This is a function of the highly specialised yellow spot, and to reach its highest level requires a more intense illumination.

(3) The colour sense, whereby we recognise different colours and colour tones. The explanation of colour vision is still quite conjectural. It is a curious fact that defects in colour vision are much commoner in males than in females, even apart from any associated disease condition.

An acquired loss of colour perception is a feature of tobacco blindness; this, too, is more common in men, since women seldom smoke the kind of tobacco which causes this condition.

Now, when we look at an object we direct both eyes into such a position that the image of the object falls upon the yellow spot in each eye, since this is our point of highest acuteness of vision. But at the same

time images of surrounding objects fall upon other portions of the retina and are perceived, although not with the same fine perception of detail. Perception by these outlying parts of the retina we call our "field vision" as distinct from our acute "central vision" by the yellow spot. This "field vision" is very important; by it we conduct much of our everyday routine of life. By it we thread our way through a crowded street, avoiding other pedestrians and warned of objects approaching us from the side; by it, too, we direct our movements in conditions of low illuminating, such as the black-out.

Certain further visual phenomena are worthy of notice. However brief the luminous impression which falls upon the retina, the effect always lasts about one-eighth of a second. After retinal excitation a series of after effects, termed "after images," may be noticed. These "after images" are divided into "positive" and "negative." These are of longer duration but lower intensity than the original or primary image. The positive image has the same distribution of brightness and colour as the original image. If we look at a bright white object and then close the eyes, a positive after image is seen, which fades slowly, passing as it fades through blue, violet, or red to orange. In negative after image bright parts appear dark, dark parts bright, and coloured parts appear in the complementary colours (e.g., red and greenish blue, orange and blue, violet and yellow). A negative after image may be produced by viewing an object steadily and then turning the eyes to a grey surface. The fact that the after image does not obtrude upon ordinary vision is largely due to the shifting of the gaze and the continual and rapid replacement of one impression by another. The after image does, in fact, favour the reception of new impressions, an important matter in the case of the eye, upon which we depend in ordinary life for a great number of impressions in any given period of time.

### Visual Requirements in Modern Life

This sketchy outline of the physiology of vision and the anatomy of the parts concerned in this sense would pave the way for some slight discussion of certain requirements of modern life if we are properly to conserve vision for ourselves and others.

The human eye was originally designed for use in the bright light of the sun, although it has a mechanism also for emergency work in low illumination. There is, however, no mechanism for fine or detailed work in poor illumination. Compared with the age-old history of man as an animal, the duration of civilisation with its increasing call upon fine work for the eyes is a mere moment. As someone has quite aptly said, "Man only came indoors yesterday"; that is to say, only comparatively recently in the history of life has man adopted a life which entails eyework in the poor light of indoor conditions. Yet throughout the ages the eye has not appreciably changed in structure or in function. Certain diseases and defects may be more common than in the past, but not owing to any essential change in the eye itself: rather in the conditions of its use. So far back as the times of the early Egyptians we have records of cases of cataract and of the operative treatment of this disease.

The efficiency of vision, the "visual acuity," may be lowered by disease of the eyes themselves, by faulty diet, by poisons, or by disease of the body affecting the system generally. In many such conditions the eyes are an important guide to the state of the individual's health, and the matter falls properly into the hands of the medical practitioner. But there remain conditions of life in which the taking of due precautions and the provision of proper surroundings are essential to secure good visual acuity and thus to ensure the individual's well-being, mental, physical, and financial.

Broadly speaking, a human being uses his eyes, more or less accurately, for 16 of the 24 hours of the day, and more accurately, rather than less, for some 7 or 8 of the 16 hours. If we remember that vision entails the constant action of small muscles and an equally constant activity of the brain centres in perception, we will readily appreciate that in a day any person uses up a great amount of nerve force in the exercise of this sense. When the reserves of nerve force begin to be exhausted we have "eye strain." The signs and symptoms of eye strain are very many and extremely various. This we would naturally expect, since no two people are alike in the amount of their nervous reserve and no two react quite alike to a reduction of this reserve force. Much will depend upon the temperament of the individual. In some this trouble will seem to be chiefly in the eyes themselves; in others the chief features will be those of general nerve exhaustion. Thus we may have heaviness of the lids, headache, and eye pains, dragging sensation in the eyes, difficulty in concentration, general irritability, and even actual vomiting. With this, of course, we find slowness and inaccuracy of work, an increase in spoiled work, and a raised accident rate. The spoiled work and increased accident rate may seriously affect the person's financial status; but more grave still is the fact that a train of symptoms beginning in this way may lead on to neurasthenia or nervous breakdown with any degree of personal discomfort as an intermediate stage.

Two measures necessary to prevent this unpleasant and harmful state are:—

(1) Correction of optical defects in the eye.
(2) Provision of adequate and suitable illumination in places of work, in which we spend many hours of life and most during which accurate vision is employed.

The two measures are placed in this order, not to indicate their relative importance, but rather to show the natural sequence that should be observed. There are other points, such as proper type for reading, adequate illumination in the house and in picture houses, but if the two stated be attended to the others will naturally follow.

**(1) Correction of optical errors.**

When a person has long sight, short sight, or astigmatism we say he has an "error of refraction," indicating that the power of his refracting media is

not normal. This will affect him in one of two ways: either he will be able to correct the error by use of his ciliary muscle or, if the defect cannot be so compensated, he must put up with blurred vision. As a matter of fact, eye strain is more marked when the defect is relatively small than when it is very large. With a small defect the ciliary muscle can maintain correction until it and the associated nerve centres are tired out, when strain makes itself manifest. With a large defect the muscle gives up the struggle and the individual resigns himself to a condition of blurred vision. This, however, is no state of blessedness, for with it we are likely to find inefficiency and a sense of inferiority. Short sight is somewhat different from the other two errors. Clear vision and vision for quite fine work may be of a high order, but this condition is so very liable to be progressive and to carry with it complications and secondary defects.

(2) **Adequate and suitable illumination.**

This aspect of our subject is approached with considerable diffidence. For while medical observers have studied the physiological effects of light and illumination upon vision, Illuminating Engineers have done an enormous amount of work on its practical application to varying human needs and have brought the scientific lighting of premises to a high pitch of efficiency, which at the same time promotes and conserves the well-being of the individual. Nevertheless, it is proposed to advance a few thoughts on ground common to both.

The waves of visible light which give to the eye, by way of its nerve elements, the sensations of light, colour, and heat are those between the length of 8,000 Angström Units and 3,900 A.U. These waves have also chemical activity and the power of imparting heat to bodies upon which they impinge. Chemical activity is greatest at the violet end of the spectrum, where they blend with the ultra-violet rays, while heating power and penetration are greatest at the red end, where they blend with the invisible infra-red rays. Occasionally eye derangements are met with which depend upon excessive action of rays at one end of the spectrum or the other.

"Snow blindness" is due to the action of ultra-violet rays reflected from the snow surface. Very few of these rays can pass through the cornea, so that the condition is not one of dazzling but rather of burning of the external parts of the eye, causing pain and watering, along with spasm and swelling of the eyelids. Similar conditions have been met with in cinema studios as the result of exposure to naked arc lights.

"Eclipse blindness," following upon looking with unprotected eyes at an eclipse of the sun, is due to an excess of rays at the other end of the spectrum. These rays pass practically unhindered to the retina and cause at first a persistent after-image and later in some cases, a blind spot—practically a burn of the retina.

In practice the troubles arising from defective illumination will not be of either of these kinds. Enclosed lights do not emit enough ultra-violet rays to cause inconvenience, nor enough infra-red to occasion burning of the tissues. The harmful results will be of the nature of eye strain; strain due to efforts to distinguish detail in a light too poor to show it adequately; constant change in adaptation of the eye and continual fluctuations in size of pupil, the confusion and retinal exhaustion consequent upon glare and the presence of hard shadows. As the intensity of illumination is increased, the eye becomes light adapted and visual acuity increases. For ordinary test types almost maximum acuity is reached with about 2 ft.c. on the types. These tests, however, require a visual effort of only very short duration. In most occupations, and particularly in those involving prolonged visual concentration and discrimination, much more than this is necessary and 50 ft.c. or more may be required, as in fine engraving, for example. Besides the intensity of the light there are other factors which influence visual acuity. Illumination must be not only adequate but also suitable for the worker.

A point of importance is the amount and character of the light falling upon the peripheral parts of the retina. A brilliantly lighted working area in a room otherwise dark necessitates rapid alterations in adaptation of the eyes which are harmful. Visual acuity is progressively improved if we increase the brightness of the surround up to about 1/10 the brightness of the test object. If the surrounds are completely dark visual acuity is lowered. General illumination of the room equal to about 1/10 that of the working area or bench favours good visual acuity and helps to prevent formation of hard and sharply defined shadows.

In any lighting proposition, and particularly when it is necessary to employ high levels of illumination for fine work, the problem of glare will present itself. Glare is the discomfort and difficulty in vision which may be experienced when light enters the eye directly from any bright source other than the object to be seen. The effect of such a glare source increases rapidly as the angle between the source and the line of vision decreases. Investigations into the effects of glare have shown some conflicting results. It has been stated that, given a sufficiently well illuminated test object, visual acuity is improved by glare, particularly when the surrounds are dark. But the effects of glare are extremely difficult to assess. They may be measured in terms of visual acuity or of personal discomfort, and the results by the two standards may be widely at variance. This is perhaps not to be wondered at when we remember the physiological and psychological elements in the faculty of vision. The discomfort effects—essentially symptoms of eye strain—are cumulative and vary greatly according to the nervous reserve of the person concerned. Visual acuity tests are usually of relatively short duration. The author cannot call to mind any experiments or investigations which have estimated the visual acuity of workers after long periods in glare conditions but after discomfort symptoms have appeared. The psychological disturbance or wastage of nervous energy resulting from continual work in glare conditions is undoubted, and certainly lowers personal efficiency. When glare is

present it is much more important to eliminate it or to minimise its effects than it is to measure these. To secure the highest level of visual acuity the eye requires a certain amount of lateral illumination and, properly planned, this will reduce the chance or intensity of glare. Glare can be obviated by indirect lighting, reflectors from ceilings, and special cornices. This is restful to the eyes and eliminates shadows, but is unsuitable for certain occupations, such as sewing. Illumination which is practically "glareless" can be achieved by a good general lighting reinforced by local lighting so screened that the eyes are shielded from direct rays from the light source.

We are concerned with *Seeing*, and seeing is a partnership of vision and illumination.

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# CORRESPONDENCE

## Population Density and the Height of Buildings

SIR,—

The Society is greatly indebted to Mr. Beckett for his masterly mathematical treatment, in the current issue of the TRANSACTIONS, of the seeming paradox of reducing obstruction to natural lighting by increasing height.

It is, however, regrettable that no mention should have been made of the extremely limited, if not negligible, extent to which it is possible to apply the paradox to practical problems in urban town planning, and the risk of ill-considered application of the principles so convincingly demonstrated.

Those who are not frequently called upon to beat the bounds of the practical limits of scientific truisms (e.g. Town Planning Committees) are very apt to reason from the particular to the general, and to assume that it is a proven scientific fact that if light, air and sunshine are to be assured in towns skyscrapers must be allowed and even encouraged.

Nothing could be further from the truth. A simple explanation of the apparent paradox is not far to seek. When an architect has to provide given accommodation on a site obviously he can obtain optimum conditions of natural lighting by housing the required floor space in premises which approximate as closely as may be practicable to a central tower of the smallest possible external dimensions taken up as high as necessary. A typical example is the cruciform plan of the London Transport building at St. James's Park. He can, however, only plan for daylight effectively on an island or peninsular site bordering on wide streets or permanently open spaces. Results on enclosed urban sites depend upon what happens, or is liable to happen, round the edges on land not under the control of the designer. It must always be borne in mind that the height to which any one ratepayer is permitted to build, on a site where it can hurt nobody, will inevitably be demanded by, and in all probability allowed to, every other ratepayer. Until the Luftwaffe destroyed it I often used to consider thoughtfully a photograph of skyscrapers on Manhattan Island with 20 out of 30 storeys using artificial light on a sunny June morning in the latitude of Madrid.

Very few urban building sites, even extensively devastated areas, are large enough to be independent of the limits to which neighbours are permitted to obstruct; and it is this which renders the paradox, important as it is, of little more than academic interest in urban town planning.

Even in situations where light, air, sunshine and increased open space could be secured by substituting ten- for five-storey dwellings, the problem of stairs obtrudes. A famous town planner once put the difficulty succinctly, "How would you like to change places with a housewife carrying a baby and a heavy shopping basket up more than four flights of stairs?" That was before the days of shopping queues and the need for reaching outdoor shelters speedily on an Alert.

Below a certain rental value per unit of dwelling floor space attended lifts are impracticable, whilst unattended automatic lifts are at the mercy of mischievous children.

Balconies also may be the *bête noir* of the natural lighting engineer, but they are the nearest approach to open-air possible to the aged, infirm and invalid marooned on the upper floors of high buildings.

Yours sincerely,

P. J. WALDRAM.

SIR,—

Mr. Waldram is quite right in pointing out that, while there may be theoretical advantages in building to greater heights, other factors in practice limit such developments. At the same time, I think that he is adopting a—for him—rather unusually timid attitude in saying that the paradox of increasing the heights of buildings in order to obtain more light is of little more than academic interest in urban town planning.

This view apparently rests on the assumption that high buildings are only practicable on open island or peninsular sites and that such opportunities are rare in a large city. But surely it is for the town planners to create the suitable sites. In the past I know that existing street patterns have come to be regarded as very unchangeable things, only to be modified by the occasional setting back of frontages to satisfy traffic needs. I believe, however, that a new outlook is now arising, which accepts the fact that many of our old street patterns are hopelessly unsuited to modern requirements, and that some rearrangement of streets must form an integral part of any reconstruction plan. This is the opportunity for which the exponents of better daylighting have long been waiting, and it is to be hoped that full advantage may be taken of it to provide many more relatively open sites for large buildings.

Mr. Waldram, of course, touches on a real difficulty when he mentions the need for lifts in high buildings. But is he correct in stating that attended lifts are impracticable in blocks of dwellings below a certain rental value? Generally, the higher one can build, the bigger can the building unit be, and this must make the lift problem easier of solution.—Yours sincerely,

Yours sincerely,

H. E. BECKETT.

# EXAMINATIONS IN ILLUMINATING ENGINEERING

### 1. Origin of the Examinations.

The Council of the Illuminating Engineering Society had been aware for some time of the need for examinations in illuminating engineering as:—

(a) Furnishing an opportunity of testing from time to time the progress of students of illumination, and setting up a standard or goal for which the students could strive;

(b) affording an indication of the acquirement of knowledge of illuminating engineering, such as should prove helpful to employers when making a selection from candidates for positions in the lighting industry;

(c) an examinational standard which could form one of the qualifications for Fellowship of the Society.

### 2. Work of the City and Guilds Institute.

The City and Guilds of London Institute, when approached on this question, took up a very friendly attitude, and as a result of the deliberations of the Advisory Committee on Illuminating Engineering, which was formed by them, a syllabus of examinations in illuminating engineering in two grades (intermediate and final) was first formed for the session 1938-39, at the end of which session the first intermediate examination was held. During the following sessions both intermediate and final examinations were held, and these have been continued each year in spite of war-time conditions.

### 3. Scope of the Syllabus.

Students intending to enter for these examinations will naturally wish to have some idea of the scope of the examinations, and for this purpose they are referred to the detailed syllabus.* It may be useful, however, to indicate some of the main divisions of the subjects on which questions are asked. These are, roughly speaking, common to both grades, but the standard is, of course, considerably higher in the final grade. The subject divisions cover the following:—

(1) Radiation and production and control of light.
(2) The Eye and Vision.
(3) Photometry.
(4) Direct Light Sources, i.e., daylight, gas burners, electric lamps of various kinds, and other light sources.
(5) Measurement and production of illumination.
(6) Lighting installations with distribution and control of illumination.

### 4. Examination Questions.

In setting the examinations the examiners have considered it desirable to give a considerable choice of questions, and it has usually been obligatory for candidates to answer not much more than half the actual number of questions set.

The following are typical of the questions set under the various sections of the syllabus.

INTERMEDIATE EXAMINATION.

1. Show, by means of a diagram, the approximate spectral energy distribution from tungsten wire run at 1,000° K. and 3,000° K., marking the limits of the visible spectrum on the diagram. State an important difference between the radiation from an incandescent gas mantle and that from a tungsten filament at the same temperature.

2. Define the term "polarised light." Describe and explain
   (a) Apparatus to polarise a beam of ordinary white light;
   (b) Apparatus to prove that the resultant beam is polarised.

3. Give a definition of each of the following terms: Lumen, lumen-hour, lumen per square foot, coefficient of utilisation, illumination, surface brightness, reflection factor.

4. Define the terms "specular" and "diffused" reflection. Illustrate your answer by diagrams. Give one illustration from industry of the use of specular reflection and one of diffused reflection.

5. Describe the phenomenon of glare. What are the factors which contribute to the reduction of glare without a reduction in illumination? Give reasons.

6. Show, by means of a full-scale diagram, the essential parts of the optical system of the eye. Explain how a young person having normal eyes can focus sharply an object in the distance and also at a short distance of, say, nine or ten inches.

7. Describe the essential parts of a globe or other integrating photometer. Prove that it integrates the total flux of light. How is the integrator standardised?

8. Give an account of one form of portable photo-electric photometer, contrasting its advantages and disadvantages with those of a portable visual instrument.

9. A lighting unit is mounted on a standard, 25 feet above the roadway. Suppose that such a source were required to yield a uniform horizontal illumination on the surface of the roadway up to a distance of 75 feet from the foot of the standard, and then to cut off completely; work out and then draw on the polar paper provided the polar curve of candle-power of the lighting unit for a value of the horizontal illumination of 0.2 foot-candle.

10. Describe a method of measuring the efficiency of a lamp in either lumens per watt, or in lumens per therm per hour. State the apparatus required for the test.

11. Give a longitudinal section of a vapour discharge lamp, and explain its operation. How does it compare in efficiency with a gas-filled electric lamp of the same wattage? How do the two types compare for street lighting.

12. Upon what factors does the amount of daylight entering a room depend? Define the terms in common use in this connection. Compare the colour of skylight and sunlight. In what kind of weather are the highest illumination values obtained?

13. Show how the remote control of a low-pressure gas unit is arranged. Explain, with the aid of a diagram, the exact operation of the switch.

14. Why were high-pressure gas distribution systems

* Given under subject number 113—Illuminating Engineering in Sectional Programme (G) of the Department of Technology of the City and Guilds Institute, published by Mr. John Murray, and obtainable from Messrs. Lamley and Co., 1-5, Exhibition-road, London, S.W.7, or from any bookseller, price 1s., postage extra (2½d.).

introduced? In what respects does the layout of the mains, and any incidental apparatus, differ from that of a low-pressure system? Illustrate your answer with sketches.

15. Determine the average effective illumination of a room measuring 30 ft. by 40 ft. illuminated by a dozen 150-watt lamps. The luminous efficiency of the lamps is to be taken as 14.0 lumens per watt, and the coefficient of utilisation as 0.35.

What percentage reduction in illumination might be expected at the end of a year. Separate the various items bringing about this reduction.

FINAL EXAMINATION—SECTION "A."

1. Draw a graph showing the distribution of energy in the spectrum of a "black body" over a wide range of wavelength. Compare on the same chart the form of the energy graph for a luminous incandescent mantle operating under normal conditions. The two are assumed to be at the same "black body" temperature.

State the law connecting the black body temperature with the total radiation, i.e., the Stefan-Boltzmann Law.

2. In broad outline describe, with the aid of a diagram, the structure of the retina.

Define peripheral and foveal vision. How do these two types of vision differ experimentally from each other?

3. Write a short essay on "Ultra-violet Light," and state its chief uses in connection with ordinary and with spectacular lighting.

4. Trace briefly the development of primary standards of light. Describe, with the aid of diagrams, the present British standard of light. What points require attention in order to obtain a reliable result?

5. Design a photo-electric photometer for producing light distribution curves of lighting fittings. Give details of the various parts of the apparatus and of the precautions to be observed during use.

6. Describe the Purkinje effect. Explain its bearing on trichromatic colour projection as affected by the intensity of the light source.

FINAL EXAMINATION—SECTION "B."

1. A lighting fitting has an intensity distribution which can be represented by the expression "$I = 200 \cos \theta$" where $\theta$ is the angle to the downward vertical and I is the intensity in candles. Draw an isolux diagram for an area 40 ft. x 20 ft. illuminated by one such fitting mounted centrally at a height of 10 ft. above the area.

2. Give a sketch of the construction of a modern high-pressure gas lamp suitable for a street lighting unit. State the advantages of using high pressure, and show how these advantages are obtained.

3. How is the spectrum of a mercury-vapour discharge lamp affected by the raising of the pressure in the tube up to many atmospheres?

What merits should such a high-pressure mercury-vapour discharge lamp have in cinema projection apparatus? What difficulties lie in the way of its practical adoption for such a purpose at present?

4. Make a list of the items about which you would wish to have information before purchasing a floodlight.

Compare the various reflecting media which could be used in its construction.

Describe one design of aerodrome floodlight and suggest a suitable performance for it.

5. What is an "isocandle diagram"? Show how to represent on it the data relating to an asymmetric luminaire (lighting unit). Prove that it does what is required. How is it used in practice?

6. Discuss carefully the question of the proper maintenance of the whole of the lighting equipment of a large factory, consisting of offices and machine shop. Show that the proposals outlined are economically sound.

## 5. How to Enter for the Examinations.

Applications for entry to the examinations should not be made direct to the City and Guilds Institute but should be made through the channel of a local technical college, preferably one where suitable preparatory classes are organised for students in illuminating engineering. The following are among the technical institutes which have provided some tuition in illuminating engineering in the past, but war-time conditions have of necessity curtailed these activities, and it may be temporarily difficult to obtain suitable tuition except in the larger industrial areas:—

**Bradford,** Technical College.
**Glasgow,** Royal Technical College.
**Halifax,** Municipal Technical College.
**Huddersfield,** Technical College.
**Leeds,** College of Technology.
**Leicester,** College of Technology.
**London and District,** Borough Polytechnic, Croydon Polytechnic, Polytechnic (Regent-street), Imperial College of Science and Technology (S. Kensington), Northampton Polytechnic, South-East London Technical Institute (Lewisham), Willesden Technical College.
**Manchester,** College of Technology.
**Middlesbrough,** Constantine Technical College.
**Newcastle-on-Tyne,** Rutherford Technical College.
**Rotherham,** College of Technology.
**Sheffield,** Central Technical College.
**Sunderland,** Technical College.
**Swindon,** The (Technical) College.
**Wolverhampton,** Technical College.

Those who have been members of the Society for a period of years or have held positions with firms in the lighting industry, will naturally have had opportunities of acquiring knowledge that may enable them to meet the requirements of the examinations.

Intending candidates for the examinations resident in areas where there are as yet no classes in illuminating engineering should write to The Superintendent, Department of Technology (City and Guilds Institute), 31, Brechin-place, London, S.W.7, who will furnish the names and addresses of secretaries of convenient local examination centres, through whom the candidates can make their entry.

The City and Guilds examinations are to be held towards the end of April or early in May each year,* i.e., at the conclusion of the winter session, and the examinations are generally arranged so as not to be spread over more than two evenings (7 p.m. to 10 p.m.)

* The next Intermediate Examination will take place on May 10, 1943, and the Final Examination on May 10 (Section "A") and May 11 (Section "B"). Entries should be received by local college examination centres before March 8.

# NOTES ON RECENT MEETINGS AND EVENTS

### Opening Sessional Meeting in London.

The Opening Sessional Meeting was held at the E.L.M.A. Lighting Service Bureau, 2, Savoy-hill, London, W.C.2, at 5 p.m., on Tuesday, October 13.

After the Minutes of the last meeting had been taken as read and approved, Mr. W. J. Jones, the retiring President, introduced Mr. R. O. Ackerley, the President for 1942-1943, who then took the Chair.

The President expressed the indebtedness of the Society to Mr. W. J. Jones for the great amount of time and attention which he had devoted to its affairs during his period of office, and also thanked Mr. E. W. Murray for his services as Hon. Treasurer during the past three years.

The President then presented the Leon Gaster Memorial Premium to Mr. J. N. Aldington for his paper on "Fluorescent Light Sources and Their Application." He pointed out that this was the first occasion on which a paper had been read initially before a Centre, and had subsequently been repeated by request in London and had received the Leon Gaster Memorial Premium. Mr. Aldington briefly expressed his appreciation of this honour.

The President then announced that the Council had that day elected Mr. J. S. Dow an Honorary Member of the Society. He recalled that the number of Honorary Members was limited to six, and that at the present time this rare distinction had been granted to only one other living member of the Society (Mr. A. P. Trotter). Mr. Dow expressed his sense of the great honour conferred on him.

The President then proceeded to deliver his address, taking as his subject "Seeing is Believing." He recalled that the dissemination of knowledge of illuminating engineering was defined as one of the primary objects of the Society, and that its first President, Professor Sylvanus P. Thompson, had emphasised the importance of this task in his inaugural address in 1909. The spread of knowledge was as fundamental a matter as the acquiring of it. The President reviewed present means of achieving this aim, e.g., through the meetings of the Society, rapidly growing in number, through contact with Government Departments and other bodies, and through its publications. He also discussed other possible channels, and in particular means of appealing to users of light.

In the concluding portion of his address the President illustrated, by means of lantern slides, the selection of pictorial material likely to arrest the attention of an audience and to supplement fitly the spoken word. He terminated his address by showing a number of simple but effective demonstrations, each conveying some fundamental lesson in regard to the application of light.

A vote of thanks to the President, proposed by Mr. C. I. Winstone and seconded by Mr. Howard Long, was carried with acclamation, and a further vote of thanks to the E.L.M.A. Lighting Service Bureau for their hospitality terminated the proceedings.

### Meetings of Centres and Groups

As will have been observed from the provisional list published in the last issue of the Transactions (September, 1942, pp. 95-96), meetings have been arranged by most of the Centres and Groups during the present month.

The Presidential Address was repeated to the Leeds Centre (North Midland Area) on October 20th, following an informal luncheon, and was also arranged to be given in Manchester (October 22nd) and Glasgow (October 28th).

An informative meeting was arranged by the Nottingham Centre (Midland Area) on October 4th, when four distinct lighting problems were introduced by different speakers.

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## Forthcoming Meetings

### SESSIONAL MEETINGS IN LONDON

**Nov. 10th.** Mr. Thos. Nisbet on **The Lighting of Docks.** (*I.E.S. Sessional Meeting, to be held at the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2*). **5.0 p.m.**

**Dec. 8th.** Discussion on **Guidance, Specification and Legislation of After-War Lighting.** (*I.E.S. Sessional Meeting, to be held in the House of the Royal Society of Arts, 6-8, John Adam Street, London, W.C.2.*) **5 p.m.**

### MEETINGS OF CENTRES AND GROUPS

**Nov. 4th.** Discussion on **Lighting of Post-war Buildings.** (*Meeting of the I.E.S. Newcastle Centre (Nth. Eastern Area), to be held in Minor Hall, Oxford Street, Newcastle-on-Tyne*). **5.30 p.m.**

**Nov. 4th.** Mr. Hugo Wood on the **Manufacture of Glassware.** (*Meeting of the I.E.S. Sheffield Group (Nth. Midland Area), to be held in the Meeting Room, Central Library, Surrey Street, Sheffield (entrance in Tudor Place*). **6.0 p.m.**

**Nov. 6th.** Dr. H. H. Barber on **The Human Eye.** (*Meeting of the I.E.S. Nottingham Centre (Midland Area), at the Gas Dept., Lecture Theatre, Parliament Street, Nottingham*). **5.30 p.m.**

**Nov. 9th.** Mr. J. H. Mollan on **The Trend of Lighting in Industry.** (*Meeting of I.E.S. Leeds Centre (North Midland Area), to be held at the College of Technology, Cookridge Street, Leeds*). **5 p.m.**

**Nov. 11th.** Mr. T. Catten on **Lighting as an Aid to War-Time Production.** (*Meeting of the I.E.S. Bath Group (Western Area) to be held in the Pump Room, Bath*)

**Nov. 17th.** Mr. S. G. Turner on **Progress of Lighting in Industry.** (*Meeting of the I.E.S. Cardiff Group (Sth. Wales Area), to be held at the Cardiff Corporation Electricity Dept., Demonstration Theatre*). **3.30 p.m.**

**Nov. 19th.** Mr. G. H. Wilson on **Street Lighting—Past, Present and Future.** (*Meeting of the I.E.S. Manchester Centre (Nth. Western Area), to be held in Reynolds Hall, College of Technology, Sackville Street, Manchester*). **2.30 p.m.**

**Nov. 20th.** Mr. R. O. Ackerley, **Presidential Address.** (*Meeting of I.E.S. Birmingham Centre (Midland Area), to be held at the Imperial Hotel, Temple Street, Birmingham*). **6.0 p.m.**

**Dec. 2nd.** Mr. C. A. Harding on **Living and Lighting in Post-War Buildings.** (*Meeting of I.E.S. Newcastle Centre (Nth. Eastern Area), to be held in the Minor Hall, Oxford Street, Newcastle-on-Tyne*). **5.30 p.m.**

**Dec. 10th.** Mr. R. O. Ackerley, **Presidential Address.** (*Meeting of Cardiff Group (Sth. Wales Area), to be held in the Cardiff Corporation Electricity Dept., Demonstration Theatre, Cardiff*). **3.30 p.m.**

**Dec. 17th.** Dr. S. English on **The Efficiency and Surface Brightness of Diffusing Lighting Fittings.** (*Meeting of I.E.S. Manchester Centre (Nth. Western Area), to be held in Reynolds Hall, College of Technology, Sackville Street, Manchester*). **2.30 p.m.**

## Honorary Membership.

The Council has elected the following to Honorary Membership in the Society:—

Dow, J. S. .....“Mayfield,” Shepherds Hill, HIGHGATE, N.

## I.E.S. Fellowship.

The following applications for Fellowship have been accepted by the Council:—

Ballin, H. H. .....The General Electric Co., Ltd., Magnet House, KINGSWAY, W.C.2.

Bearman, C. W. ...Public Works Dept., Government Buildings, Wellington, C.1, NEW ZEALAND.

## Additions to List of Members.

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the List of Members:

SUSTAINING MEMBERS:—

Abell and Smith's Electric Co., Ltd., Electra House, Angel Place, WORCS.
*Representative*:—Horton Smith, H.

B. French, Ltd. ...Mill Street, KIDDERMINSTER.
*Representative*:—French, B.

W. T. Hellaby and Co., Ltd. .....80, Dale End, BIRMINGHAM, 4.
*Representative*:—Hellaby, W. T.

The Midland Electric Installation Co., Ltd. .....Upper Villiers Street, WOLVERHAMPTON.
*Representative*:—Joseph, R. A.

Reynolds and Bradwell .....57, Colmore Row, BIRMINGHAM, 3.
*Representative*:—Reynolds, E. A.

Speedy and Eynon, Ltd. .....39, Carrs Lane, BIRMINGHAM.
*Representative*:—Whaley, R. S.

F. W. Thorpe, Ltd. Welby Road, Hall Green, BIRMINGHAM.
*Representative*:—Thorpe, E. G.

The Wardle Engineering Co., Ltd. ...Old Trafford, MANCHESTER, 16.
*Representative*:—Gordon, J. H.

CORPORATE MEMBERS:—

Aish, Norman .....Yelverton Road, BOURNEMOUTH.

Andrew, H. L. ...“Bowstone,” Gawsworth Road, MACCLESFIELD.

Capell, R. G. .....66b, Pembroke Road, Clifton, BRISTOL, 8.

Cheyne, A. J. .....“Newlands,” Bents Drive, SHEFFIELD, 11.

Gurney, E. W. M. “Dene Knowle,” Cold Blow, Bexley, KENT.

Howard, A. V. ...56, Letchworth Road, LEICESTER.

John, L. .....61, Polwarth Road, E. Brunton, NEWCASTLE-ON-TYNE, 3.

Longthorne, J.....13, Grove Terrace, Frizinghall, BRADFORD.

McDonald, H. .....“Braemar,” Sleethmorr Lane, Somercoates, DERBY.

Piggott, C. W. .....Mersey Dynamo Works, Range Road, Stockport, CHESHIRE.

Pyne, H. J. .....The Pynes, 11, Withers Road, Bilbrook, Nr. WOLVERHAMPTON.

Rutherford, J. W. E. Adamson and Co. (Tyne), Ltd., 30, Handyside Arcade, Percy Street, NEWCASTLE-ON-TYNE.

Smith, H. D. .....60, Sutton Passeys Crescent, Wollaton Park, NOTTINGHAM.

Wolloch, J. .....134, Parkville Road, Withington, MANCHESTER, 20.

Woolley, J. W. ...53, Woodville Road, Golders Green, LONDON, N.W.11.

TRANSFERS FROM COUNTRY TO CORPORATE MEMBERSHIP:—

Harris, C. .....30, High Drive Avenue, Chilwell, NOTTS.

Hillier, R. .....225, Tullebardine Road, Ecclesall, SHEFFIELD.

McAllister, E. P. ...Cill Clauna, Stillorgan, Co. DUBLIN.

## Additions to Library

Mr. A. P. Trotter has kindly made the following presentations to the I.E.S. Library:—

| TITLE. | AUTHOR. |
|---|---|
| The Universe of Light ..... | Sir William Bragg. |
| The Science of Illumination ... | Dr. L. Bloch. |
| The Mechanism of Nature ... | Dr. E. N. da C. Andrade. |
| Electrical Photometry and Illumination ..... | Hermann Bohle. |
| Illumination and Photometry.. | William Elgin Wickenden. |

In addition, Mr. Trotter has presented some bound volumes of “The Illuminating Engineer,” containing records of early meetings of the Society, certain letters from Prof. A. Blondel, and reprints of contributions on photometry and illumination, and a framed portrait of Bouguer, who has been described as “the father of photometry,” which is intended to be hung in the room at 32, Victoria Street, in which the library is at present housed.

*The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.*

*With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—“Trans. Illum. Eng. Soc. (London).”*

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